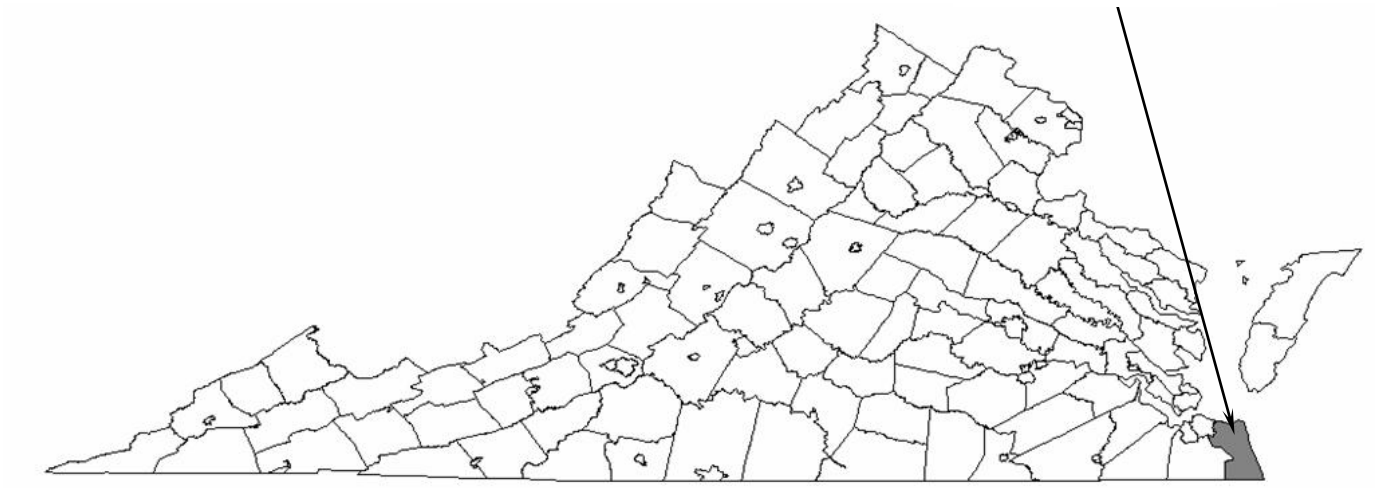
FLOOD INSURANCE STUDY

CITY OF VIRGINIA BEACH, VIRGINIA

INDEPENDENT CITY



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JANUARY 16, 2015

Federal Emergency Management Agency
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NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) report may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Part or all of this FIS report may be revised and republished at any time. In addition, part of this FIS report may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the FIS report. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS report components.

Initial FIS Report Effective Date: October 3, 1970

Revised FIS Report Dates:	July 1, 1974	To change zone designations
	October 8, 1976	To reflect curvilinear flood boundary and to add Special Flood Hazard Areas (SFHAs)
	July 17, 1984 (FIS report); January 17, 1985 (Flood Insurance Rate Map)	To add detailed riverine and wave height analysis
	December 5, 1990	To change SFHAs, to add roads and road names, and to reflect updated topographic information
	August 18, 1992	To add Otherwise Protected Areas, to decrease Base Flood Elevations, to change SFHAs, to add roads and road names, and to reflect updated topographic information
	December 5, 1996	To update corporate limits and map format, to change Base Flood Elevations, SFHAs, to reflect updated topographic information, and to modify Coastal Barrier Resource System units
	May 4, 2009	To update corporate limits, road and road names, to incorporate previously issued Letters of Map Revision, to reflect updated topographic information, and to change SFHAs
	January 16, 2015	To incorporate new detailed Coastal Flood Hazard Analyses and to update map format

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FLOOD INSURANCE STUDY
CITY OF VIRGINIA BEACH, VIRGINIA, INDEPENDENT CITY

1.0 INTRODUCTION

1.1 Purpose of Study

This FIS revises and updates information on the existence and severity of flood hazards in the geographic area of the City of Virginia Beach, Virginia, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood-risk data for various areas of the community that will be used to establish actuarial flood insurance rates and to assist the community in its efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the State (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgements

The sources of authority for this FIS are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses for the FIS report dated July 17, 1984, and the FIRM dated January 17, 1985, (hereinafter referred to collectively as the 1985 revision) were prepared by the U.S. Army Corp of Engineers (USACE), Norfolk District, for the Federal Emergency Management Agency (FEMA), under Inter-Agency Agreement No. EMW-E-0105, Project Order No. 10. That work was completed in February 1983. The FIS report was created in the 1985 revision.

In the December 5, 1990 revision, updated topographic information for the Stumpy Lake watershed was prepared by the City of Virginia Beach, under agreement with FEMA. Undated topographic information for the Charlestowne Lake South area was also included in the revision. That work was completed in December 1989.

In the August 18, 1992 revision, the hydrologic and hydraulic analyses were prepared by the USACE, Norfolk District. That work was completed in April 1991.

In the December 5, 1996 revision, the hydraulic analyses were prepared by the USACE, Norfolk District, for FEMA under Inter-Agency Agreement No. EMW-91-E-3525, Project Order No. 1. This work was completed in March 1993.

In the May 4, 2009 revision, Michael Baker Jr. completed the digital conversion and redelineation under contract agreement HSFEHQ-04-D-0025, and the work was completed in December 2007.

For the May 4, 2009 revision, base map data was provided by the City of Virginia

Beach. Planimetric and terrain data from aerial survey data captured in March of 2004, at a scale of 1" =600', was prepared by Sanborn in June 2005. The Sanborn aerial survey also captured Light Detection and Ranging (LiDAR) data, from which was derived the bare-earth LiDAR data, Digital Terrain Models (DTMs), and 2 foot contours. The special flood hazards were redelineated on this new terrain data (Reference 1).

For this January 16, 2015 revision, detailed coastal flood hazard analyses were performed for several flooding sources. The study replaces outdated coastal storm surge stillwater elevations for all FISs in the study area, including the City of Virginia Beach, and serves as the basis for updated FIRMs. Study efforts were initiated in 2008 and concluded in 2012. The FEMA Region III office initiated a study in 2008 to update the coastal storm surge elevations within the states of Virginia, Maryland, and Delaware, and the District of Columbia including the Atlantic Ocean, Chesapeake Bay including its tributaries, and the Delaware Bay. The storm surge study was conducted for FEMA by the USACE and its project partners under Project HSFE03-06-X-0023, "NFIP Coastal Storm Surge Model for Region III" and Project HSFE03-09-X-1108, "Phase II Coastal Storm Surge Model for FEMA Region III". The work was performed by the Coastal Processes Branch (HF-C) of the Flood and Storm Protection Division (HF), U.S. Army Engineer Research and Development Center – Coastal & Hydraulics Laboratory (ERDC-CHL). The topographic data for the coastal floodplain mapping was prepared by Dewberry, for the U.S. Geological Survey (USGS) and FEMA, under Contracts G10PC00013 and G11PD0089.

Base map information shown on this FIRM was obtained from the City of Virginia Beach Center for Geospatial Information Services, including hydrography and political boundaries. These files were compiled at a scale of 1" = 600' or better based on aerial photography captured in March, 2004. Additional information may have been derived from other sources (Reference 2).

The projection used in the preparation of this map was the Virginia State Plane South zone (FIPSZONE 4502). The horizontal datum was the North American Datum of 1983 (NAD83) HARN, GRS80 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

1.3 Coordination

The purpose of an initial Consultation Coordination Officer's (CCO) meeting is to discuss the scope of the FIS. A final CCO meeting is held to review the results of the study.

For the 1985 revision, an initial CCO meeting was held on May 12, 1980 and was attended by representatives from FEMA, the City of Virginia Beach, the Virginia State Water Control Board, and the USACE. A search for basic data was made at all levels of government. A final CCO meeting was held on February 3, 1984.

For the 1996 revision, an initial CCO meeting was held on April 11, 1990 with representatives from the City of Virginia Beach, the USACE and FEMA. On July 18, 1990, a meeting was held with representatives from the city, USACE and FEMA to review FEMA standards for Geographic Information System (GIS) computer mapping and to compare FEMA standards with the computer mapping system presently used by the City of Virginia Beach. A coordination meeting was held with representatives from the City of Virginia Beach and the USACE on August 15, 1990. On May 16, 1991 an interagency meeting was held with representatives from the City of Virginia Beach, the USACE, and FEMA to review objectives of the study, schedules and standards and specifications regarding digital FIRMs. Various coordination meetings were held with the Department of Public Works, Surveys and Mapping Bureau, and the City of Virginia Beach regarding the digital mapping products.

For the May 4, 2009 revision, an initial CCO meeting was held on January 25, 2006 with representatives from FEMA and the USACE Norfolk District along with the City of Virginia Beach Department of Public Works, Department of Communications, and the Virginia Beach Center for Geospatial Information Services. The results of this study were reviewed at the final CCO meeting held on February 19, 2008, and attended by representatives of FEMA, the City of Virginia Beach, and Michael Baker Jr. Inc. All problems raised at that meeting have been addressed in the May 4, 2009 study.

For this January 16, 2015 revision, an initial CCO meeting was held on March 22, 2011, and attended by representatives of the City of Virginia Beach, USACE, and FEMA. A final CCO meeting was held on May 23, 2013, with representatives of FEMA, the City of Virginia Beach, and the study contractor.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the City of Virginia Beach, Virginia.

The following flooding sources were studied by detailed methods: Lake Smith Tributary, Lake Pembroke, Thalia Creek, Left Bank Tributary Tahlia Creek, Holland Road Tributary Thalia Creek, Pine Tree Branch, Canal No. 2 London Bridge Creek, Canal No. 2 West Neck Creek, Holland Road Corridor System, Green Run Canal, Mill Dam Creek, Canal No. 1 North, Fox Run Canal, Lake Banbury, Cedar Hill Canal, Salem Canal, Canal No. 4, and Colony Acres Canal. Tidal flooding from the Atlantic Ocean and the Chesapeake Bay and their adjoining estuaries, including the effects of high-velocity wave action that accompanies severe storms such as hurricanes and northeasters, was also studies by detailed methods.

Limits of detailed study are indicated on the Flood Profiles (Exhibit 1) and on the FIRM (Exhibit 2). The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction.

The December 5, 1990 revision incorporated updated topographic information and floodplain boundaries for areas of approximate study known as Stumpy Lake Watershed and Charlestowne Lakes South, located immediately west of Stumpy Lake.

For the August 18, 1992 revision, Canal No. 2 London Bridge Creek, was revised from Virginia Beach Boulevard to a point approximately 0.8 mile upstream of Shipps Corner Road. Canal No. 2 West Neck Creek, was revised from West Neck Road to a point approximately 1.7 miles upstream of the confluence of Colony Acres Canal. This revision was performed to reflect the completion of a channelization project for Canal No. 2, London Bridge Creek, and Canal No. 2 West Neck Creek. The project provided a new canal for a length of 2.6 miles and channelization of the existing canal for a length of 1.1 miles. The Canal No. 2 watershed has a drainage area of approximately 37 square miles. In addition, Holland Road Corridor System, Green Run Canal, and Colony Acres Canal were revised to reflect the changes in backwater from Canal No. 2 and to reflect updated topographic information.

For the 1996 revision, 28 miles of shoreline along the Atlantic Ocean and 10 miles of shoreline on the Chesapeake Bay were restudied, including all military and Federal installations, state parks and wildlife refuges. The coastal analyses in this revision were based on the stillwater elevations used in the previously printed FIS for the City of Virginia Beach. Fox Run Canal and Left Bank Tributary Thalia Creek were restudied for their entire lengths within the community. Lake Smith and Lake Smith Tributary were changed from Zone AE (EL 7) to approximate Zone A because the normal pool elevation is 7.3 feet and a 1-percent-annual-chance flood elevation had not been established. Flood boundaries for all remaining tidal areas and fluvial streams studied in detail were redelineated using the latest topographic data. As a result of the filling of Kings Point System, flood hazards no longer exist for that stream.

All or portions of the following streams were studied by approximate methods: Pleasure House Lake, Lake Edward, Thalia Creek, Holland Road Tributary Tahlia Creek, Lake Christopher, Stumpy Lake, Lake Smith, Lake Smith Tributary, Lake Lawson, Green Run Canal, and several small areas with unknown sources. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon, by FEMA and the City of Virginia Beach.

For the May 4, 2009 revision, Letters of Map Revision (LOMRs) 00-03-083P and 06-03-B810P were incorporated, a vertical datum conversion from the National Geodetic Vertical Datum of 1929 (NGVD 29) to the North American Vertical Datum of 1988 (NAVD 88) was applied, and partial foot Base Flood Elevations (BFEs) were placed and delineated for coastal stillwater areas.

In this January 16, 2015 revision, the Atlantic Ocean and Chesapeake Bay were restudied. This restudy affects Back Bay, Bradford Lake, Broad Bay, Chubb Lake, Eastern Branch Elizabeth River, Lake Christine, Lake Holly, Lake Taylor, Linkhorn Bay, Lynnhaven Bay, Lynnhaven River, Rudee Inlet, and Western Branch Lynnhaven River.

This January 16, 2015 revision also incorporates the determinations of LOMRs issued by FEMA, as shown in Table 1, "Letters of Map Change".

TABLE 1 – LETTERS OF MAP CHANGE

Type	Case Number	Effective Date	Project Identifier
LOMR	12-03-2078P	April 11, 2013	Lynnhaven Shores, Block 2, Lots 16A & 18A

2.2 Community Description

The City of Virginia Beach is located in the southeastern corner of Virginia. It is bordered by the Atlantic Ocean to the east; the Chesapeake Bay to the north; the cities of Norfolk and Chesapeake to the west; and the unincorporated areas of Currituck County, North Carolina to the south. The 2010 Census places the population at 437,994 (Reference 3). The city has a total land area of 258.7 square miles. Within the city are thousands of acres of farmland, five military installations, 28 miles of oceanfront, 10 miles of bay front, and 51.3 square miles of inland water. Agriculture, Federal installations and tourism are the mainstays of the city's economy.

Princess Anne County, which was named for the daughter of James II who later became Queen Anne, was formed in 1691 from lower Norfolk County. Although the first English settlers in the New World landed at Cape Henry in 1607, they later sailed up the James River to form the Jamestown Colony. The first settlement in what is now Virginia Beach was established in 1621, on Lynnhaven Bay. In 1822, the county seat of Princess Anne County was moved from Kempsville to Princess Anne, which is the present site of the Municipal Center Complex of Virginia Beach (Reference 4).

Virginia Beach was incorporated as a town in 1906 and became an independent city in 1952. In 1963, the city was greatly enlarged by a merger with Princess Anne County. An arm of the Eastern Branch Elizabeth River enters the city from the west. In the southern part of the city are the broad expanses of Back Bay and Broad Bay. Important inland waterways include Rudee Inlet and Lake Holly, which are tidal inlets of the Atlantic Ocean, and Lynnhaven Bay, Broad Bay, Linkhorn Bay, and Like Creek, which are tidal estuaries of the Chesapeake Bay. Lake Smith and Stumpy Lake are sizable landlocked bodies of water within the city.

The floodplains of Virginia Beach abound with commercial, industrial and residential developments and public utilities. Most of the development in Virginia Beach has taken place in the northern half of the city. The southern half remains essentially rural, with farming the principal occupation. There is some manufacturing within the city, but most of the residents find employment in manufacturing industries in surrounding cities or in Federal installations. In addition, many people are engaged in the tourist industry.

Virginia Beach is situated in the Coastal Plain province and is underlain primarily by unconsolidated sand and clay strata. The terrain is essentially flat, with ground elevations averaging approximately 12 feet. Small areas, mostly in the form of sand

dunes, rise about 15 feet. Shallow waters of less than 20 feet fringe the coastal shoreline, and depths in the inland bays and connecting waters are generally less than 10 feet.

The city enjoys a temperate climate with moderate seasonal changes. The climate is characterized by moderately warm summers with temperatures averaging 78 degrees Fahrenheit (°F) in July, the warmest month. The winters are cool with temperatures averaging 41°F in January, the coolest month. The average annual precipitation is approximately 45 inches. There is some variation in the monthly averages; however, rainfall is distributed evenly throughout the year. Snowfall is infrequent, generally occurring in light amounts which normally melt within 24 hours (Reference 4).

A drainage divide represents the upstream limit of two distinct hydrologic subareas within the area of interest. For Canal No. 2 London Bridge Creek, and Canal No. 2 West Neck Creek, the drainage divide is located at the cross section labeled Q and L on the respective streams. The riverine discharges during a 1-percent-annual-chance riverine flood event will flow away from this point in opposite directions through each of the above referenced bodies of water.

2.3 Principal Flood Problems

The coastal areas of Virginia Beach are vulnerable to tidal flooding from major storms commonly referred to as hurricanes and northeasters. Both types of storms produce winds that push large volumes of water against the shore.

Hurricanes, with their high winds and heavy rainfall, are the most severe storms that hit the area. The term “hurricane” is applied to an intense cyclonic storm originating in tropical or subtropical altitudes in the Atlantic Ocean just north of the Equator. A study of the tracks of all tropical storms for which there is a record indicates that, on an average of once a year, a tropical storm of hurricane force passes within 250 miles of the area and poses a threat to Virginia Beach. While hurricanes can affect the area from May through November, nearly 80 percent occur in the months of August, September and October, with approximately 40 percent occurring in September. The most severe hurricane to strike the area occurred in August 1933. Other notable hurricanes that caused significant flooding in Virginia Beach were those of September 1933, September 1936 and September 1960 (Reference 5).

Another type of storm that can cause severe damage to the city is the northeaster. This is also a cyclonic-type storm and originates with little or no warning along the middle and northern Atlantic Coast. Northeasters occur most frequently in the winter, but can occur at any time. Accompanying winds are not of hurricane force, but are persistent, causing above-normal tides for long periods of time. The March 1962 northeaster was the worst to hit the study area. Other northeasters that caused significant flooding in Virginia Beach included those of March 1927, October 1948 and April 1956 (Reference 5).

The depth of flooding during hurricanes and northeasters depends upon the velocity, direction and duration of the wind, the size and depth of the body of water over which the wind is acting, and the astronomical tide. For instance, strong and persistent

northerly and easterly winds will cause flooding of the shorelines of the Chesapeake Bay, the Atlantic Ocean and their connecting inland waterways. Flooding in the Back Bay and North Landing River areas is caused by strong winds from a southerly direction. As would be expected, because of the larger size of the water bodies involved, flooding along the shorelines of the Chesapeake Bay, the Atlantic Ocean, and the Elizabeth River occurs in greater depth than flooding in the southern portion of the city. Simultaneous flooding of both the outer coastal areas and southern bay areas of the city is not possible, except in rare events where the surge-producing forces cause either the destruction or overtopping of the barrier dunes that separate the Atlantic Ocean from the inland waters in the southern portion of the city. The duration of the flooding depends upon the duration of the tide producing forces. Floods caused by a hurricane are usually of much shorter duration than the ones caused by a northeaster. Flooding from hurricanes rarely lasts more than one tidal cycle, whereas flooding caused by northeasters can last several days, during which the most severe flooding takes place at the time of the peak astronomical tide.

The timing or coincidence of the maximum storm surge with the normal high tide is an important factor in the consideration of flooding from tidal sources. Tidal waters in the study area normally fluctuate twice daily from an elevation of 1.7 feet to -1.7 feet in the Atlantic Ocean and from 1.4 to -1.4 feet in the Chesapeake Bay and the Elizabeth River. The range of fluctuations is somewhat less in most of the connecting interior waterways. There are no measurable astronomical tides in Back Bay or the North Landing River.

The study area also contains numerous estuaries of the Atlantic Ocean and the Chesapeake Bay that are subject to tidal flooding in their lower reaches. Flooding in the upper reaches of these streams can be caused by heavy rains occurring anytime throughout the year. Flooding can also occur as a result of an intense rainfall produced by local summer thunderstorms, or tropical disturbances, such as hurricanes, that move into the area from the Gulf of Mexico or Atlantic Coast. Flood heights on these streams can rise from normal to extreme flood peaks in a relatively short period of time. The duration of flooding depends on the duration of runoff producing rainfall. In some cases, floods may last for a couple of days, whereas floods occurring as a result of short duration summer thunderstorms usually rise to a maximum peak stage and subside to near normal levels in less than a day.

All development in the floodplains is subject to water damage. Additionally, some areas, depending on exposure, are subject to high velocity wave action, which can cause structural damage and severe erosion along beaches. Waves are generated by the action of wind on the surface of water. The entire Virginia Beach shoreline is vulnerable to wave damage because of its vast exposure afforded by the Chesapeake Bay and the Atlantic Ocean. Virginia Beach has experienced major storms since the early settlement of the area. Historical accounts of severe storms in the area date back several hundred years. The following paragraphs discuss some of the larger known floods that have occurred. This information is based on newspaper accounts, historic records, field investigations and routing data collection programs normally carried out by the Norfolk District of USACE.

The earliest storm of record causing extensive damage in the Virginia Beach area occurred on March 2-3, 1927. Practically all damage inflicted on the city resulted from the high tide of Wednesday night, March 2. This storm undermined or flanked most of the protective structures in existence and severely damaged or destroyed the majority of them. The beaches were almost completely denuded of the overlying sand. All along the beach, the sea washed the sand away, leaving the clay undersoil exposed. The greatest damage was in the vicinity of the main resort area where a large hotel and many other structures were severely damaged.

The eye of the August 1933 hurricane passed directly over Virginia Beach, and the storm surge caused the most extensive flooding in the city in the past 200 years or more. In most parts of the city, the maximum storm surge was the greatest of record and occurred about 3 hours before, but persisted throughout the peak of the astronomical tide. Maximum tidal elevations, either estimated or observed, were 8.6 feet for the Atlantic Coast and Lynnhaven Bay, 8.0 feet for the Eastern Branch Elizabeth River, approximately 5.3 feet for Broad and Linkhorn Bays, and approximately 3.8 feet in the Back Bay and North Landing River areas. Extensive damage to waterfront property and low-lying buildings occurred during this storm. High waves caused much of the structural damage in exposed areas along the open coast. In addition to damage from tidal flooding, much damage was caused to roofs, communication lines and other structures by the high winds.

A northeaster struck the Virginia coastline on October 4, 1948 and continued for several days. It reached maximum intensity on October 5 with tide elevations reaching 5.1 feet in nearby Norfolk. Wind velocities at Cape Henry varied from 30 to 45 miles per hour, with gusts up to 60 miles per hour from the northeast. The boardwalk was severely buffeted for its entire length, and the greatest damage was sustained between 17th Street and 7th Street. This storm also moved a considerable amount of sand from the beach, creating conditions similar to those caused by the March 1927 storm.

Another flood occurred on April 11, 1956 as a result of another northeaster. The storm produced a steady northeast wind in the Virginia Beach area for approximately 30 hours. The tides were approximately 4 feet above normal for 12 hours and produced the maximum tidal crest on the morning of the 11th. Damage to structures was light; however, a considerable amount of sand eroded from the beaches.

A tidal stage of major proportions occurred during the northeaster of March 6-8, 1962. Disastrous flooding and high waves occurred along the Atlantic Seaboard from New York to Florida. This flood was unusual even for a northeaster, since it was caused by a low pressure cell that moved from south to north past Virginia Beach, and then reversed its course, moving again to the south. Huge volumes of water and high waves battered the mid-Atlantic coastline for several days.

The maximum flood height at Virginia Beach associated with this northeaster occurred on the morning of March 7 and reached approximately 5.7 feet on the Atlantic coast. Extensive flooding and much damage resulted along the Atlantic Ocean, the Chesapeake Bay and their connecting waterways. The hardest hit sections of the city were Sandbridge Beach, the area from Rudee Inlet to 49th Street, North Virginia Beach above

57th Street, and Ocean Park on the Chesapeake Bay. Tidal heights reached during this storm were the second highest of record in the area, but were almost 2 feet lower than those reached in the August 1933 hurricane. The damage, however, was the greatest of any storm in the area due to the increased development along the shoreline since 1933. Another contributing factor was that tides during this storm remained above normal for 4 days. High waves added to the structural damage caused by the high water. Severe eroding of the beaches and shorefront also occurred. The seawall fronting the main resort area in the city was seriously damaged. Estimates of damage in Virginia Beach were more than 8 million dollars. The aforementioned water levels are indicative of stages experienced in the eastern and northern sections of the city. Stages in Back Bay and the North Landing River tend to be lowered by northeast winds, and thus, were inconsequential during the 1962 storm.

2.4 Flood Protection Measures

There are a number of measures that have afforded some protection against minor flooding. These include a concrete bulkhead and promenade, stone, steel and wooden bulkheads, sand dunes, and non-structural measures for floodplain management, such as zoning and building codes.

The City of Virginia Beach/USACE Beach Erosion Control and Hurricane Protection Project created a structure that affords 140-year level of protection from coastal storms between Rudee Inlet and 89th Street. The sea wall structure was certified by the USACE as noted in documentation dated 10/18/2006.

A concrete bulkhead and promenade was constructed by local interests in 1927. It extends from 7th Street to 35th Street and consists essentially of a vertical-faced wall and a concrete deck that is approximately 20 feet wide at an elevation of 11.4 feet. At various times during the period from 1938 to 1952, the structure suffered severe storm damage. In 1953 and 1954, the wall was restored by the Virginia Beach Erosion Commission. During the March 1962 storm, the wall was again severely damaged and emergency repairs were made by the USACE. Wood and steel bulkheads, which were also constructed by local interests, extend from 35th Street to 49th Street. Light wooden bulkheads have been built along portions of the Chesapeake Bay, but have proven ineffective as flood protection measures. Within the 28 miles of ocean shoreline, there are approximately 20 miles of sand dunes that vary in height from 12 feet to 25 feet. These dunes afford considerable protection to adjoining property.

The city has passed ordinances as required by FEMA to qualify for the Regular Program of the NFIP. These measures are found in Article 12 of the city's Comprehensive Zoning Ordinance – Flood Plain Regulations. These requirements, along with others such as, Article 16, the Coastal Primary Sand Dune Zoning Ordinance, have been beneficial in reducing the risk of future flood damage in the community.

3.0 ENGINEERING METHODS

For the flooding sources studied by detail methods in the county, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. For example, the risk of having a flood which equals or exceeds the 1-percent- annual-chance flood in any 50-year period is approximately 40 percent (four in ten); for any 90-year period, the risk increases to approximately 60 percent (six in ten). The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak elevation-frequency relationships for the flooding source studied in detail affecting the community.

Information on the methods used to determine peak discharge-frequency relationships for the streams studied by detailed methods is shown below.

For the streams studied by detailed methods, it was necessary to develop flood frequencies by synthetic means because there are no records of streamflow and no available high-water data to permit development of flood-stage frequency relationships. The lack of adequate streamflow records required an analysis of rainfall and runoff characteristics of the watersheds in determining frequency estimates. These analyses involved the application of rainfall-runoff amounts to a synthetic graph (unit hydrograph). Based on hydraulic parameters (slope, length, drainage areas, channel “n” values and time of concentration) determined for the streams, unit graphs were developed for several locations on each stream using the Clark method. Rainfall-frequency values selected from Technical Paper No. 40 were then applied to the unit graphs to obtain the desired discharge frequencies (Reference 6). In the August 18, 1992 revision, the hydraulic parameters used were based on a fully developed and completely sewered Canal No. 2 watershed.

For the January 16, 2015 revision, no new detailed hydrologic analyses were carried out.

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 2, “Summary of Discharges”.

TABLE 2 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	Cubic Feet per Second (CFS) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
CANAL NO. 1 NORTH					
At Virginia Beach Boulevard	3.5	230	300	330	390
At a point approximately 850 feet upstream of Norfolk Southern Railroad	0.9	360	520	610	820
CANAL NO. 2 LONDON BRIDGE CREEK					
At Virginia Beach Boulevard	13.7	2,140	3,120	3,960	5,970
CANAL NO 2. WEST NECK CREEK					
At Indian River Road	19.0	2,470	3,670	4,380	6,730
CANAL NO. 4					
At its confluence with Salem Canal	5.9	1,420	2,080	2,420	3,260
CEDAR HILL CANAL					
At its confluence with the Eastern Branch Elizabeth River	3.2	170	270	330	470
COLONY ACRES CANAL					
At its confluence with Canal No.2 West Neck Creek	5.7	950	1,400	1,630	2,200
FOX RUN CANAL					
At Lord Dunsmore Drive	1.5	620	890	1,030	1,390
At Brandywine Drive	0.5	320	460	530	720
GREEN RUN CANAL					
At its confluence with Canal No. 2 West Neck Creek	1.5	340	480	570	760
HOLLAND ROAD CORRIDOR SYSTEM					
At its confluence with Green Run Canal	1.4	230	340	390	530
HOLLAND ROAD TRIBUTARY THALIA CREEK					
At its confluence with Left Bank Tributary Thalia Creek	1.3	640	910	1,050	1,420
LAKE BANBURY					
At its confluence with the Eastern Branch Elizabeth River	1.2	750	1,060	1,210	1,640
At Indian River Road	0.5	470	660	750	1,010

TABLE 2 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	Cubic Feet per Second (CFS) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
LEFT BANK TRIBUTARY THALIA CREEK					
At its confluence with Thalia Creek	2.5	990	1,430	1,650	2,230
LAKE PEMBROKE					
Upstream side of Independence Boulevard	1.6	1,050	1,440	1,640	2,160
Downstream side of Independence Boulevard	1.6	550	780	900	1,190
LAKE SMITH TRIBUTARY					
At its confluence with Lake Smith	1.8	340	520	610	820
MILL DAM CREEK					
At a point approximately 2,500 feet downstream of Mill Dam Road	1.1	510	740	850	1,150
PINE TREE BRANCH					
At its confluence with the Eastern Branch Lynnhaven River	0.9	170	200	230	320
SALEM CANAL					
At the confluence of Canal No. 4	5.0	1,270	1,850	2,140	2,890
At Recreation Drive	1.4	370	530	620	840
THALIA CREEK					
At the Norfolk Southern Railroad Crossing	5.7	900	1,220	1,290	1,490

3.2 Hydraulic Analyses

Hydraulic analyses, considering storm characteristics and the shoreline and bathymetric characteristics of the flooding source studied, were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along the shoreline.

Cross sections and bridge data used in the backwater computations for the riverine flooding sources were obtained from field surveys, “as-built” subdivision plans, Virginia Department of Highways drawings and topographic maps (References 7-8).

Due to the drainage divide located at cross section L on Canal No. 2 West Neck Creek and, at the same location, cross section Q on Canal No. 2 London Bridge Creek, the computed water-surface elevations are not in agreement. This cross section represents

the meeting point of the analyses for Canal No. 2 London Bridge and Canal No. 2 West Neck Creeks.

Locations of selected cross sections used in the hydraulic analyses are on the Flood Profiles (Exhibit 1) and are also shown on the FIRM (Exhibit 2). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations and modeling information is shown in Table 5, "Floodway Data" (see Page 31).

Water-surface elevations of floods of the selected recurrence intervals were computed using the USACE HEC-2 step-backwater computer program (Reference 9). Starting water-surface elevations were calculated using the slope/area method. Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals.

Roughness factors (Manning's "n") used in the hydraulic computations were determined on the basis of field inspection of the streams and floodplains areas and engineering judgment. The channel "n" values for all the riverine flooding sources, except Canal No. 2 London Bridge Creek and Canal No. 2 West Neck Creek, ranged from 0.025 to 0.045, and the overbank "n" values ranged from 0.045 to 0.100. For Canal No. 2 London Bridge Creek and Canal No. 2 West Neck Creek, the channel "n" value was 0.040, and the overbank "n" value was 0.100.

For the 1996 revision, Fox Run Canal and Left Bank Tributary Thalia Creek were restudied to eliminate discrepancies in the base map topography. The cross sections and bridges were field surveyed to obtain elevation data and structural geometry. Channel roughness factors were assigned based on field inspection and engineering judgment. In addition, the 1- and 0.2-percent-annual-chance Special Flood Hazard Area (SFHA) boundaries for all riverine flooding sources were revised based on updated topographic maps (Reference 8).

For the January 16, 2015 revision, no new hydraulic analyses were carried out.

Qualifying bench marks (elevation reference marks) within a given jurisdiction that are cataloged by the National Geodetic Survey (NGS) and entered into the National Spatial Reference System (NSRS) as First or Second Order Vertical and have a vertical stability classification of A, B, or C are shown and labeled on the FIRM with their 6-character NSRS Permanent Identifier.

Bench marks cataloged by the NGS and entered into the NSRS vary widely in vertical stability classification. NSRS vertical stability classifications are as follows:

- Stability A: Monuments of the most reliable nature, expected to hold position / elevation well (e.g., mounted in bedrock)
- Stability B: Monuments which generally hold their position / elevation well (e.g., concrete bridge abutment)
- Stability C: Monuments which may be affected by surface ground movement (e.g., concrete monument below frost line)

- Stability D: Mark of questionable or unknown stability (e.g., concrete monument above frost line, or steel witness post)

In addition to NSRS bench marks, the FIRM may also show vertical control monuments established by a local jurisdiction; these monuments will be shown on the FIRM with the appropriate designations. Local monuments will only be placed on the FIRM if the community has requested that they be included, and if the monuments meet the aforementioned NSRS inclusion criteria.

To obtain current elevation, description, and/or location information for bench marks shown on the FIRM for this jurisdiction, please contact the Information Services Branch of the NGS at (301) 713-3242, (Internet address www.ngs.noaa.gov).

It is important to note that temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with this FIS and FIRMs. Interested individuals may contact FEMA to access this data.

3.3 Coastal Analysis

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. USACE has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones (Reference 10). The 3-foot wave has been determined as the minimum size wave capable of causing major damage to conventional wood frame veneer structures.

The methodology for analyzing the effects of wave heights associated with coastal storm surge flooding is described in the National Academy of Sciences report (Reference 11). This method is based on three major concepts. First, depth-limited waves in shallow water reach a maximum breaking height that is equal to 0.78 times the still water depth, and the wave crest is 70 percent of the total wave height above the still water level. The second major concept is that the wave height may be diminished by the dissipation of energy due to the presence of obstructions such as sand dunes, dikes, seawalls, buildings, and vegetation. This study incorporates the effects of marsh vegetation on wave heights as described in Procedures for Applying Marsh Grass Methodology (Reference 12). The amount of energy dissipation is a function of the physical characteristics of the obstruction and is determined by procedures described in References 4 and 5. The third major concept is that wave height can be regenerated in open fetch areas due to the transfer of wind energy to the water. This added energy is related to fetch length and depth.

Figure 1, “Transect Schematic”, is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in the county may not include all the situations illustrated in Figure 1.

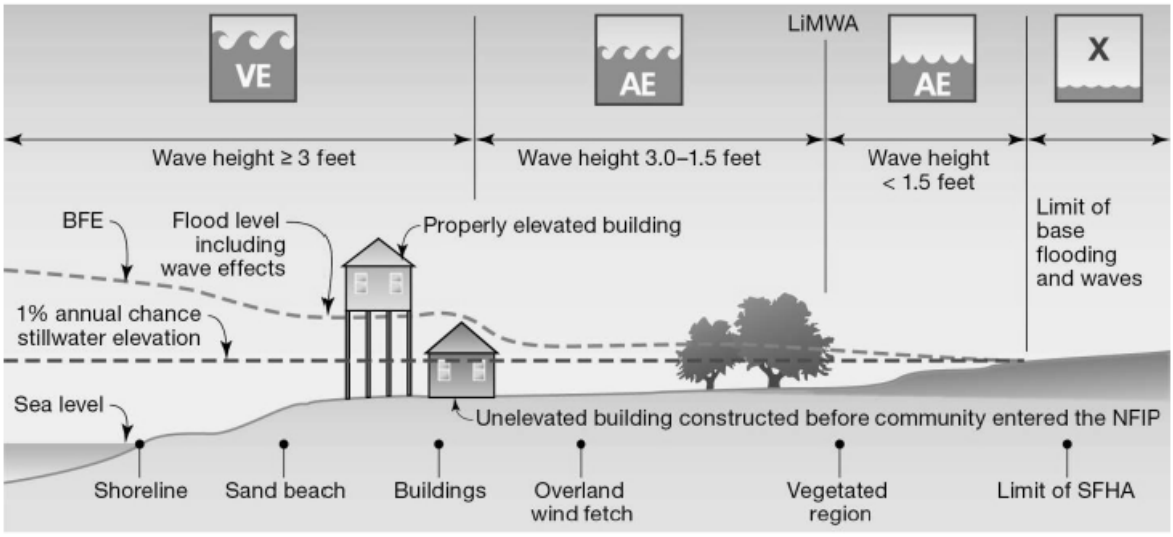


FIGURE 1 - TRANSECT SCHEMATIC

Coastal analysis, considering storm characteristics and the shoreline and bathymetric characteristics of the flooding sources studied, were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along the shoreline. Users of the FIRM should be aware that coastal flood elevations are provided in Table 3, "Summary of Stillwater Elevations" in this report. If the elevation on the FIRM is higher than the elevation shown in this table, a wave height, wave runup, and/or wave setup component likely exists, in which case, the higher elevation should be used for construction and/or floodplain management purposes.

Development along the coast of the City of Virginia Beach is extensive, beginning at the confluence of Little Creek, along Chesapeake Bay, and extending to the southern limit of Sand Bridge, along the Atlantic Ocean. Undeveloped areas extend from the southern limits of Sand Bridge to the North Carolina state line, as well as the western shoreline of Back Bay. Portions of these areas are located within the Back Bay National Wildlife Refuge and False Cape State Park. The entire coastline is comprised of a small dune whose elevation varies from four feet to more than nine feet, with the exception of an area of wide flat beach, between 55th Street and southward to Rudee Inlet. Behind the dune, the ground slopes down to largely developed areas.

The end-to-end storm surge modeling system includes the Advanced Circulation Model for Oceanic, Coastal and Estuarine Waters (ADCIRC) for simulation of 2-dimensional hydrodynamics (Reference 13). ADCIRC was dynamically coupled to the unstructured numerical wave model Simulating WAves Nearshore (unSWAN) to calculate the contribution of waves to total storm surge (Reference 14). The resulting model system is typically referred to as SWAN+ADCIRC (Reference 14). A seamless modeling grid was developed to support the storm surge modeling efforts. The modeling system validation consisted of a comprehensive tidal calibration followed by a validation using carefully reconstructed wind and pressure fields from three major flood events for the Region III domain: Hurricane Isabel, Hurricane Ernesto, and Extratropical Storm Ida.

Model skill was accessed by quantitative comparison of model output to wind, wave, water level and high water mark observations.

The tidal surge in the Atlantic Ocean and Chesapeake Bay affects the entire 360 miles of the City of Virginia Beach coastline. The northern and eastern coastlines, from Little Creek, eastward to Cape Henry, and southward to the North Carolina state line, are more prone to damaging wave action during high wind events due to the significant fetch over which winds can operate. The widths of several embayments, including Lynnhaven Bay, Broad Bay, Shipps Bay, Redhead Bay, and Back Bay narrow considerably. In these areas, the fetch over which winds can operate for wave generation is significantly less.

The storm-surge elevations for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods determined for the flooding sources are shown in Table 3, "Summary of Stillwater Elevations." The analyses reported herein reflect the stillwater elevations due to tidal and wind setup effects.

TABLE 3 - SUMMARY OF STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD*) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
ATLANTIC OCEAN				
At Cape Henry	4.7	6.0	6.6	7.7
At the Virginia/North Carolina State Line	5.1	6.5	6.9	8.1
CHESAPEAKE BAY				
At Little River	4.9	6.4	7.0	8.5
At Cape Henry	4.6	5.9	6.4	7.6
BACK BAY				
At North Bay	1.0	1.9	2.6	3.7
At Deal Creek	0.7	1.2	1.5	2.1
BRADFORD LAKE				
Entire shoreline within community	5.1	6.5	7.1	8.5
BROAD BAY				
Entire shoreline within community	4.9	6.1	6.5	7.8
CHUBB LAKE				
Entire shoreline within community	5.1	6.5	7.1	8.4
EASTERN BRANCH ELIZABETH RIVER				
Entire shoreline within community	5.8	7.1	7.9	10.2
LAKE CHRISTINE				
Entire shoreline within community	5.2	5.7	6.2	7.5
LAKE HOLLY				
Entire shoreline within community	5.2	6.6	7.1	8.4

TABLE 3 - SUMMARY OF STILLWATER ELEVATIONS - continued

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD*) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
LAKE TAYLOR Entire shoreline within community	5.5	6.9	7.5	9.4
LINKHORN BAY Entire shoreline within community	5.0	6.0	6.5	8.2
LYNNHAVEN BAY Entire shoreline within community	5.3	6.5	7.1	8.6
LYNNHAVEN RIVER Entire shoreline within community	5.1	6.4	6.9	8.4
RUDEE INLET Entire shoreline within community	5.2	6.6	7.1	8.4
WESTERN BRANCH LYNNHAVEN RIVER Entire shoreline within community	5.4	6.7	7.3	8.9

*North American Vertical Datum of 1988

The coastal analysis and mapping for the City of Virginia Beach was conducted for FEMA by RAMPP under contract No. HSFEHQ-09-D-0369, Task Order HSFE03-09-0002. The coastal analysis involved transect layout, field reconnaissance, erosion analysis, and overland wave modeling including wave setup, wave height analysis and wave runup.

Wave heights were computed across transects that were located along coastal and inland bay areas of the City of Virginia Beach, as illustrated on the FIRM. The transects were located with consideration given to existing transect locations and to the physical and cultural characteristics of the land so that they would closely represent conditions in the locality.

Each transect was taken perpendicular to the shoreline and extended inland to a point where coastal flooding ceased. Along each transect, wave heights and elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features, as illustrated in Figure 2, “Transect Location Map”.

The stillwater elevations for a 1-percent-annual-chance event were used as the starting elevations for these computations. Wave heights were calculated to the nearest 0.1 foot, and wave elevations were determined at whole-foot increments along the transects. The location of the 3-foot breaking wave for determining the terminus of the Zone VE (area with velocity wave action) was computed at each transect. Along the open coast, the Zone VE designation applies to all areas seaward of the landward toe of the primary frontal dune system. The primary frontal due is defined as the point where the ground profile changes from relatively steep to relatively mild.

Dune erosion was taken into account along both the Chesapeake Bay and Atlantic Ocean coastline. A review of the geology and shoreline type in the City of Virginia Beach was made to determine the applicability of standard erosion methods, and FEMA's standard erosion methodology for coastal areas having primary frontal dunes, referred to as the "540 rule," was used (Reference 15). This methodology first evaluates the dune's cross-sectional profile to determine whether the dune has a reservoir of material that is greater or less than 540 square feet. If the reservoir is greater than 540 square feet, the "retreat" erosion method is employed and approximately 540 square feet of the dune is eroded using a standardized eroded profile, as specified in FEMA guidelines. If the reservoir is less than 540 square feet, the "remove" erosion method is employed where the dune is removed for subsequent analysis, again using a standard eroded profile. The storm surge study provided the return period stillwater elevations required for erosion analyses. Each cross-shore transect was analyzed for erosion, when applicable.

Wave height calculations used in this study flood the methodologies described in the FEMA guidance for coastal mapping (Reference 15). Wave setup results in an increased water level at the shoreline due to the breaking of waves and transfer of momentum to the water column during hurricanes and severe storms. For the City of Virginia Beach study, wave setup was determined directly from the coupled wave and storm surge model. The total stillwater elevation (SWEL) with wave setup was then used for simulations of inland wave propagation conducted using FEMA's Wave Height Analysis for Flood Insurance Studies (WHAFIS) model Version 4.0 (Reference 16). WHAFIS is a one-dimensional model that was applied to each transect in the study area. The model uses the specified SWEL, the computed wave setup, and the starting wave conditions as input. Simulations of wave transformations were then conducted with WHAFIS taking into account the storm-induced erosion and overland features of each transect. Output from the model includes the combined SWEL and wave height along each cross-shore transect allowing for the establishment of BFEs and flood zones from the shoreline to points inland within the study area.

Wave runup is defined as the maximum vertical extent of wave uprush on a beach or structure. FEMA's 2007 Guidelines and Specifications require the 2-percent-annual-chance wave runup level be computed for the coastal feature being evaluated (cliff, coastal bluff, dune, or structure) (Reference 15). The 2-percent-annual-chance runup level is the highest 2-percent-annual-chance of wave runup affecting the shoreline during the 1-percent-annual-chance flood event. Each transect defined within the FEMA Region III study area was evaluated for the applicability of wave runup, and if necessary, the appropriate runup methodology was selected and applied to each transect. Runup elevations were then compared to WHAFIS results to determine the dominant process affecting BFEs and associated flood hazard levels. Based on wave runup rates, wave overtopping was computed following the FEMA 2007 Guidelines and Specifications.

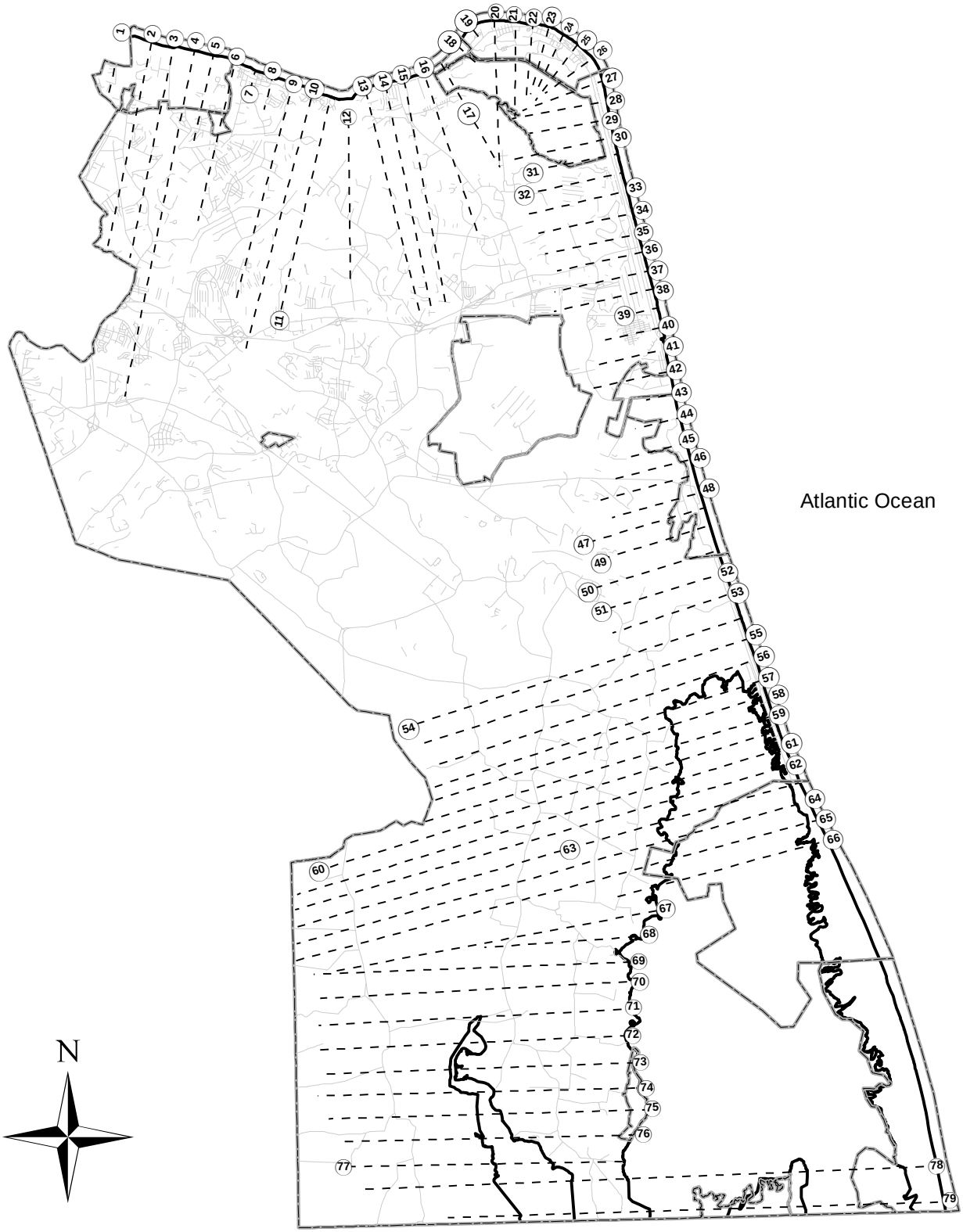


FIGURE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VIRGINIA (INDEPENDENT CITY)

0 1 2 4 6 8 Miles

TRANSECT LOCATION MAP

Computed controlling wave heights along the shoreline range from 4.0 to 5.3 feet in the Chesapeake Bay, from 4.7 to 5.6 feet in the Atlantic Ocean where the fetch is long to a range of 0.1 to 1.9 feet in Back Bay, where the fetch is short. The corresponding wave elevation along the shoreline varies from 9.8 to 11.0 feet in the Chesapeake Bay, 9.6 to 11.6 feet in the Atlantic Ocean and 2.5 feet to 7.2 feet in Back Bay. The dune along the coast serves to reduce wave height transmitted inland, but the large areas of low-lying marshes which are inundated by the tidal surge allow regeneration of the waves as they proceed inland. In general, the relatively shallow depth of water in the marshes along with the energy dissipating effects of vegetation allows only minor regeneration of the waves.

Between transects, elevations were interpolated using topographic maps, land-use and land cover data, and engineering judgment to determine the aerial extent of flooding. The results of the calculations are accurate until local topography, vegetation, or cultural development within the community undergo major changes. Table 4, "Transect Data", provides the Atlantic Ocean, Chesapeake Bay, and Back Bay 10-, 2-, 1- and 0.2-percent-annual-chance stillwater elevations and the starting wave conditions for each transect.

TABLE 4 - TRANSECT DATA

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY	1	N 36.92989 W -76.18057	11.6	7.1	5.1	6.5	7.1	8.5
CHESAPEAKE BAY	2	N 36.92820 W -76.16871	11.5	7.2	5.1	6.5	7.1	8.5
CHESAPEAKE BAY	3	N 36.92643 W -76.16014	11.9	7.1	5.1	6.4	7.0	8.5
CHESAPEAKE BAY	4	N 36.92516 W -76.15188	11.6	7.2	5.0	6.4	6.9	8.4
CHESAPEAKE BAY	5	N 36.92349 W -76.14442	11.8	7.3	5.1	6.5	7.0	8.4
CHESAPEAKE BAY	6	N 36.92128 W -76.13576	11.7	7.0	5.1	6.5	7.1	8.5

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY	7	N 36.91814 W -76.12803	11.4	7.0	5.1	6.5	7.0	8.4
CHESAPEAKE BAY	8	N 36.91611 W -76.12120	11.2	6.8	5.1	6.4	7.0	8.4
CHESAPEAKE BAY	9	N 36.91358 W -76.11365	11.1	6.6	5.1	6.4	6.9	8.4
CHESAPEAKE BAY	10	N 36.91142 W -76.10526	11.0	6.5	5.1	6.4	6.9	8.5
CHESAPEAKE BAY	11	N 36.90948 W -76.09827	11.0	6.5	5.1	6.4	7.0	8.5
LYNNHAVEN RIVER	12	N 36.90109 W -76.09152	3.9	6.8	5.2	6.5	7.0	8.4
CHESAPEAKE BAY	13	N 36.91172 W -76.08456	10.5	6.4	5.0	6.3	6.8	8.3
CHESAPEAKE BAY	14	N 36.91326 W -76.07654	10.5	6.3	5.0	6.2	6.8	8.2
CHESAPEAKE BAY	15	N 36.91429 W -76.06910	10.5	6.3	4.9	6.1	6.7	8.1
CHESAPEAKE BAY	16	N 36.91635 W -76.06113	10.3	6.2	4.8	6.1	6.6	8.0
CHESAPEAKE BAY	17	N 36.91942 W -76.05436	10.3	6.2	4.8	6.1	6.6	8.0
CHESAPEAKE BAY	18	N 36.92492 W -76.04768	10.2	6.1	4.7	6.0	6.5	7.8
CHESAPEAKE BAY	19	N 36.93015 W -76.04464	11.8	6.1	4.6	5.9	6.4	7.6
ATLANTIC OCEAN	20	N 36.93220 W -76.03272	11.8	6.2	4.6	5.8	6.3	7.6

TABLE 4 – TRANSECT DATA (continued)

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ATLANTIC OCEAN	21	N 36.93170 W -76.02436	12.2	6.1	4.6	5.9	6.4	7.6
ATLANTIC OCEAN	22	N 36.93111 W -76.01748	12.6	6.8	4.6	5.8	6.3	7.5
ATLANTIC OCEAN	23	N 36.92994 W -76.01108	12.7	8.1	4.7	5.9	6.4	7.6
ATLANTIC OCEAN	24	N 36.92794 W -76.00565	12.9	9.2	4.8	6.0	6.6	7.6
ATLANTIC OCEAN	25	N 36.92412 W -75.99998	13.3	12.1	4.8	6.1	6.6	7.7
ATLANTIC OCEAN	26	N 36.91954 W -75.99423	12.3	14.0	4.9	6.2	6.7	8.0
ATLANTIC OCEAN	27	N 36.91229 W -75.99046	13.1	14.3	4.8	6.1	6.7	7.7
ATLANTIC OCEAN	28	N 36.90558 W -75.98877	12.4	15.0	4.7	6.1	6.6	7.8
ATLANTIC OCEAN	29	N 36.90080 W -75.98778	12.9	14.4	4.8	6.2	6.7	7.9
ATLANTIC OCEAN	30	N 36.89423 W -75.98665	13.1	13.6	5.0	6.3	6.8	8.1
ATLANTIC OCEAN	31	N 36.88894 W -75.98510	13.4	13.5	4.9	6.3	6.8	8.0
ATLANTIC OCEAN	32	N 36.88294 W -75.98325	12.5	13.3	4.9	6.3	6.8	8.0
ATLANTIC OCEAN	33	N 36.87794 W -75.98150	12.5	13.3	4.9	6.3	6.8	8.0
ATLANTIC OCEAN	34	N 36.87012 W -75.97935	12.5	13.3	4.9	6.3	6.8	8.0

TABLE 4 – TRANSECT DATA (continued)

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ATLANTIC OCEAN	35	N 36.86357 W -75.97734	12.7	13.3	4.9	6.3	6.9	8.1
ATLANTIC OCEAN	36	N 36.85777 W -75.97565	12.8	13.3	4.9	6.3	6.8	8.1
ATLANTIC OCEAN	37	N 36.85160 W -75.97391	13.0	12.8	4.9	6.3	6.8	8.1
ATLANTIC OCEAN	38	N 36.84587 W -75.97241	12.9	13.3	5.0	6.3	6.9	8.1
ATLANTIC OCEAN	39	N 36.83977 W -75.97089	13.0	13.4	5.0	6.4	7.0	8.2
ATLANTIC OCEAN	40	N 36.83357 W -75.96932	13.2	13.5	5.1	6.5	7.1	8.3
ATLANTIC OCEAN	41	N 36.82660 W -75.96829	13.7	13.4	5.2	6.6	7.1	8.4
ATLANTIC OCEAN	42	N 36.81951 W -75.96685	13.8	13.4	5.1	6.5	7.0	8.3
ATLANTIC OCEAN	43	N 36.81241 W -75.96524	14.0	13.3	5.2	6.6	7.1	8.3
ATLANTIC OCEAN	44	N 36.80460 W -75.96324	14.2	13.3	5.3	6.7	7.2	8.4
ATLANTIC OCEAN	45	N 36.79661 W -75.96081	14.3	13.3	5.2	6.6	7.2	8.4
ATLANTIC OCEAN	46	N 36.79129 W -75.95925	14.4	13.3	5.3	6.6	7.1	8.4
ATLANTIC OCEAN	47	N 36.78640 W -75.95792	14.6	13.3	5.3	6.6	7.1	8.3
ATLANTIC OCEAN	48	N 36.78065 W -75.95617	14.7	13.3	5.2	6.6	7.1	8.3

TABLE 4 – TRANSECT DATA (continued)

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ATLANTIC OCEAN	49	N 36.77577 W -75.95443	15.0	13.3	5.2	6.6	7.1	8.3
ATLANTIC OCEAN	50	N 36.77014 W -75.95246	15.6	12.0	5.1	6.6	7.1	8.3
ATLANTIC OCEAN	51	N 36.76226 W -75.94957	16.3	12.0	5.2	6.5	7.1	8.3
ATLANTIC OCEAN	52	N 36.75519 W -75.94687	16.8	12.1	5.2	6.6	7.1	8.3
ATLANTIC OCEAN	53	N 36.74862 W -75.94425	17.0	12.1	5.3	6.6	7.1	8.3
ATLANTIC OCEAN	54	N 36.74047 W -75.94141	17.3	12.2	5.1	6.5	7.0	8.2
ATLANTIC OCEAN	55	N 36.73387 W -75.93883	17.9	12.4	5.1	6.5	7.1	8.3
ATLANTIC OCEAN	56	N 36.72719 W -75.93590	17.9	12.7	5.1	6.5	7.0	8.3
ATLANTIC OCEAN	57	N 36.72066 W -75.93350	18.0	12.7	5.2	6.6	7.1	8.3
ATLANTIC OCEAN	58	N 36.71478 W -75.93134	18.0	12.6	5.2	6.6	7.1	8.3
ATLANTIC OCEAN	59	N 36.70929 W -75.92922	17.7	12.6	5.2	6.6	7.1	8.3
ATLANTIC OCEAN	60	N 36.70453 W -75.92747	18.2	12.6	5.2	6.6	7.1	8.2
ATLANTIC OCEAN	61	N 36.69887 W -75.92517	18.2	12.1	5.2	6.6	7.2	8.3
ATLANTIC OCEAN	62	N 36.69348 W -75.92282	18.1	12.3	5.2	6.6	7.1	8.3

TABLE 4 – TRANSECT DATA (continued)

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ATLANTIC OCEAN	63	N 36.68767 W -75.92027	18.1	12.0	5.2	6.6	7.0	8.2
ATLANTIC OCEAN	64	N 36.68159 W -75.91714	18.1	12.7	5.2	6.6	7.0	8.2
ATLANTIC OCEAN	65	N 36.67547 W -75.91375	17.6	12.7	5.3	6.7	7.1	8.3
ATLANTIC OCEAN	66	N 36.66894 W -75.90993	18.6	13.1	5.3	6.7	7.2	8.3
BACK BAY	67	N 36.64828 W -75.97768	2.4	3.5	0.6	1.5	1.9	2.8
BACK BAY	68	N 36.64030 W -75.98433	3.3	3.4	0.6	1.5	1.9	2.8
BACK BAY	69	N 36.63221 W -75.98917	3.2	3.1	0.6	1.5	1.9	2.8
BACK BAY	70	N 36.62609 W -75.98760	2.2	2.7	0.6	1.5	1.8	2.6
BACK BAY	71	N 36.61725 W -75.98891	2.3	2.7	0.6	1.4	1.8	2.5
BACK BAY	72	N 36.60883 W -75.99154	1.0	2.3	0.6	1.5	2.0	2.7
BACK BAY	73	N 36.60015 W -75.98881	1.1	2.2	0.6	1.4	1.8	2.4
BACK BAY	74	N 36.59202 W -75.98704	1.0	2.3	0.6	1.4	1.7	2.4
BACK BAY	75	N 36.57713 W -75.98993	1.0	2.2	0.6	1.3	1.6	2.2

TABLE 4 - TRANSECT DATA (continued)

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations (feet NAVD88) Range of Stillwater Elevations (feet NAVD88)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
BACK BAY	76	N 36.57713 W -75.98993	0.7	2.2	0.6	1.4	1.8	2.5
BACK BAY	77	N 36.56879 W -75.99317	0.5	3.5	0.6	1.5	1.9	2.7

3.4 Vertical Datum

All FIS reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum used for newly created or revised FIS reports and FIRMs was the NGVD 29. With the completion of the NAVD 88, many FIS reports and FIRMs are now prepared using NAVD 88 as the referenced vertical datum.

All flood elevations shown in this FIS report and on the FIRM are referenced to NAVD 88. Structure and ground elevations in the community must, therefore, be referenced to NAVD 88. It is important to note that adjacent communities may be referenced to NGVD 29. This may result in differences in base flood elevations across the corporate limits between the communities.

As noted above, the elevations shown in the FIS report and on the FIRM for the City of Virginia Beach are referenced to NAVD 88. Ground, structure, and flood elevations may be compared and/or referenced to NGVD 29 by applying a standard conversion factor. The conversion factor from NGVD 29 to NAVD 88 for the City of Virginia Beach is -0.96 foot.

For more information on NAVD 88, see Converting the National Flood Insurance Program to the North American Vertical Datum of 1988, FEMA Publication FIA-20/June 1992, or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242
http://www.ngs.noaa.gov/

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. Therefore, each FIS provides floodplain data, which may include a combination of the 10-percent-annual-chance, 2-percent-annual chance, 1-percent-annual-chance, and 0.2-percent-annual-chance flood elevations, delineations of the 1-percent-annual-chance and 0.2-percent-annual-chance floodplains, and the 1-percent-annual-chance floodway to assist communities in developing floodplain management measures. This information is presented on the FIRM and in many components of the FIS report, including the Summary of Stillwater Elevations table, and Transect Data table. Users should reference the data presented in the FIS report as well as additional information that may be available at the local map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent-annual-chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent-annual-chance flood is employed to indicate additional areas of flood risk in the community.

The 1- and 0.2-percent-annual-chance floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the 1-percent-annual-chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, AH, AO, A99, V and VE), and the 0.2-percent-annual-chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent-annual-chance floodplain boundaries are close together, only the 1-percent-annual-chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

In the December 5, 1990 revision, the 1-percent-annual chance floodplain in the area known as Charlestowne Lakes South was redelineated using updated topographic mapping and a City of Virginia Beach flood hazard study based on a stormwater management plan (References 17-19). The 1-percent-annual chance floodplain for the Stumpy Lake watershed was redelineated using the same mapping sources.

For the May 4, 2009 revision, detailed studied streams had the 1- and 0.2-percent-annual-chance floodplain boundaries delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:2400 with a contour interval of 2 feet (Reference 1). This revision also changed a portion Canal No. 4 from a detailed study AE zone to an approximate A zone, starting upstream of cross-section “O”. This was done to reflect recent alteration of the streambed not accounted for in the modeling. The revised portion was delineated as an approximate A zone loosely based on the previous BFEs.

For the areas studied by approximate methods, the 1-percent-annual-chance floodplain boundaries are based on normal depth calculations, storage, previous studies, and the engineer's familiarity and experience with similar streams in the study area. The 1-percent-annual-chance floodplain boundaries were delineated based on topographic information (Reference 7).

For the areas studied by approximate methods, only the 1-percent-annual chance floodplain boundary is shown on the FIRM (Exhibit 2).

In this January 16, 2015 revision, areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The USACE has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones (Reference 10). The 3-foot wave has been determined the minimum size wave capable of causing major damage to conventional wood frame of brick veneer structures. The one exception to the 3-foot wave criteria is where a primary frontal dune exists. The limit the coastal high hazard area then becomes the landward toe of the primary frontal dune or where a 3-foot or greater breaking wave exists, whichever is most landward. The coastal high hazard zone is depicted on the FIRM as Zone VE, where the delineated flood hazard includes wave heights equal to or greater than three feet. Zone AE is depicted on the FIRM where the delineated flood hazard includes wave heights less than three feet. A depiction of how the Zones VE and AE are mapped is shown in Figure 1.

Post-storm field visits and laboratory tests have confirmed that wave heights as small as 1.5 feet can cause significant damage to structures when constructed without consideration to the coastal hazards. Additional flood hazards associated with coastal waves include floating debris, high velocity flow, erosion, and scour which can cause damage to Zone AE-type construction in these coastal areas. To help community officials and property owners recognize this increased potential for damage due to wave action in the AE zone, FEMA issued guidance in December 2008 for identifying and mapping the 1.5-foot wave height line, referred to as the Limit of Moderate Wave Action (LiMWA). While FEMA does not impose floodplain management requirements based on the LiMWA, the LiMWA is provided to help communicate the higher risk that exists in that area. Consequently, it is important to be aware of the area between this inland limit and the Zone VE boundary as it still poses a high risk, though not as high of a risk as Zone VE (see Figure 1).

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent-annual-chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent-annual-

chance flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections in Table 5, "Floodway Data." The computed floodways are shown on the FIRM (Exhibit 2). In cases where the floodway and 1-percent-annual-chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

For the May 4, 2009 revision, the floodways were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections in Table 5, "Floodway Data" The computed floodways are shown on the FIRM (Exhibit 2). In cases where the floodway and 1-percent-annual-chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown. Due to the unusual flooding conditions for Lake Pembroke, no floodway was delineated.

For the May 4, 2009 revision, the floodways from the 1996 revision were incorporated. Slight alterations were made to account for changes in the streambed location and floodplain geometry. Where necessary the SFHA was widened to fully contain the modeled floodway width. Additionally, Canal No. 4 had its floodway trimmed to account for alteration of the stream location in the vicinity of Recreation Drive.

The area between the floodway and 1-percent-annual-chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent-annual-chance flood more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 3, "Floodway Schematic".

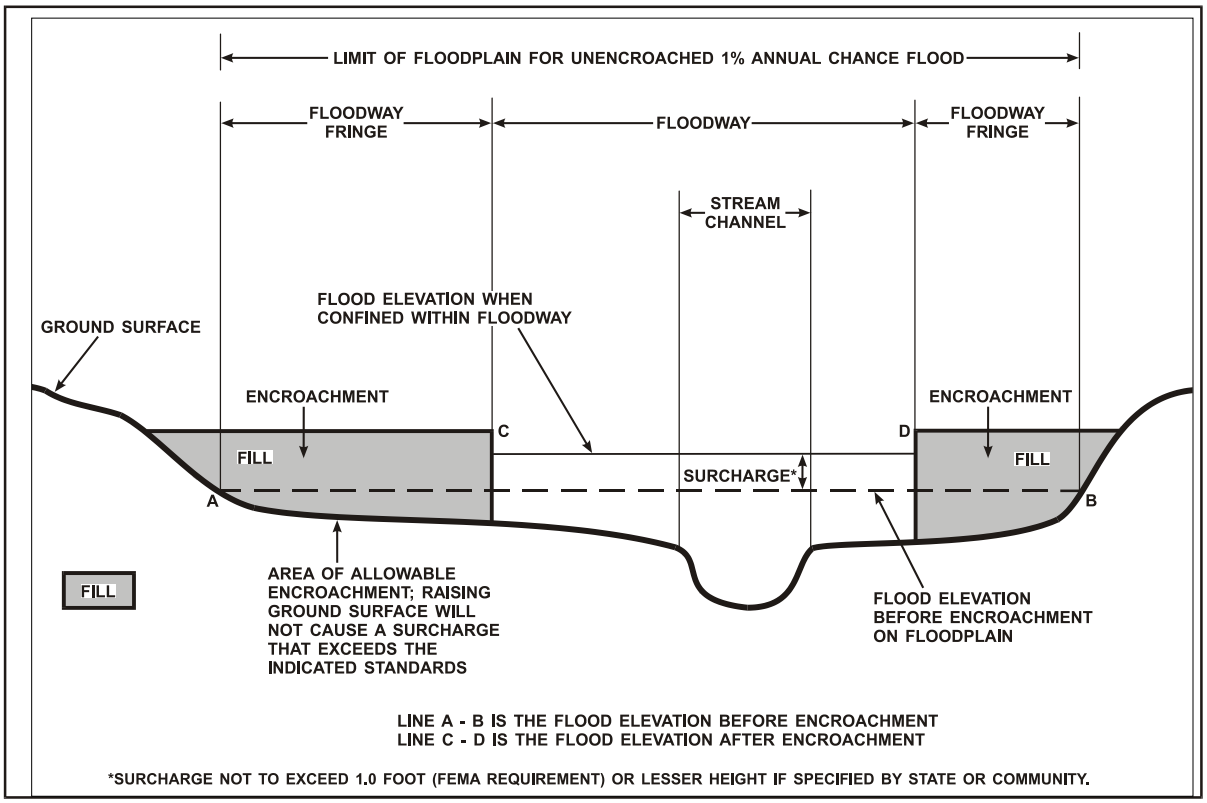

LIMIT OF FLOODPLAIN FOR UNENCROACHED 1% ANNUAL CHANCE FLOOD
FLOODWAY FRINGE
FLOODWAY
FLOODWAY FRINGE
STREAM CHANNEL
FLOOD ELEVATION WHEN CONFINED WITHIN FLOODWAY
GROUND SURFACE
ENCROACHMENT
ENCROACHMENT
C
D
FILL
FILL
SURCHARGE*
A
B
FILL
AREA OF ALLOWABLE ENCROACHMENT; RAISING GROUND SURFACE WILL NOT CAUSE A SURCHARGE THAT EXCEEDS THE INDICATED STANDARDS
FLOOD ELEVATION BEFORE ENCROACHMENT ON FLOODPLAIN
LINE A - B IS THE FLOOD ELEVATION BEFORE ENCROACHMENT
LINE C - D IS THE FLOOD ELEVATION AFTER ENCROACHMENT
*SURCHARGE NOT TO EXCEED 1.0 FOOT (FEMA REQUIREMENT) OR LESSER HEIGHT IF SPECIFIED BY STATE OR COMMUNITY.

Figure 3 – Floodway Schematic

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
CANAL NO. 1 NORTH								
A	4,430	400[2]	1,640	0.9	8.4	8.4	8.4	0.0
B	4,965	600[2]	1,490	0.4	8.5	8.5	8.5	0.0
C	6,085	300[2]	980	0.6	8.6	8.6	8.6	0.0
D	6,790	106	470	1.2	8.8	8.8	9.8	1.0
E	7,260	104	320	1.7	9.1	9.1	10.1	1.0
F	7,910	86	250	2.1	10.3	10.3	11.3	1.0
G	8,930	132	450	1.1	11.5	11.5	12.4	0.9

[1]Feet above Virginia Beach Norfolk Expressway

[2]Storage-type Analysis

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

CANAL NO. 1 NORTH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
CANAL NO. 2 LONDON BRIDGE CREEK								
A	405	205[2]	1,565	2.5	6.9	4.1[3]	5.1	1.0
B	1,455	209	1,685	2.4	6.9	4.4[3]	5.3	0.9
C	2,500	150[2]	1,710	2.3	6.9	4.6[3]	5.5	0.9
D	3,690	172[2]	1,740	2.2	6.9	4.8[3]	5.7	0.9
E	4,720	150	1,795	2.0	6.9	5.0[3]	5.9	0.9
F	6,660	250	1,710	0.9	6.9	5.2[3]	6.1	0.9
G	7,930	150	1,225	1.2	6.9	5.3[3]	6.2	0.9
H	9,335	150	1,120	1.2	6.9	5.5[3]	6.3	0.8
I	10,220	100	1,105	1.2	6.9	5.5[3]	6.4	0.9
J	11,490	100	1,135	1.1	6.9	5.7[3]	6.5	0.8
K	13,775	100	1,155	0.8	6.9	5.8[3]	6.6	0.8
L	14,450	100	1,425	0.6	6.9	5.8[3]	6.6	0.8
M	16,230	100	1,270	0.6	6.9	5.8[3]	6.6	0.8
N	19,840	100	920	0.4	6.9	5.9[3]	6.7	0.8
O	20,885	100	750	1.7	6.9	5.9[3]	6.7	0.8
P	23,540	300	1,595	0.4	6.1	6.1	6.9	0.8
Q	27,150	600	3,095	0.0	6.2	6.2	6.9	0.7

[1]Feet above Westbound Lane Virginia Beach Boulevard

[2]Floodway width adjusted to updated waterlines, does not match model

[3]Elevation computed without consideration of backwater effects from Eastern Branch Lynnhaven River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

CANAL NO. 2 LONDON BRIDGE CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
CANAL NO. 2 WEST NECK CREEK								
A	10,540	2,200	9,075	0.5	3.5	3.5	4.5	1.0
B	11,400	1,600	6,785	0.6	3.6	3.6	4.6	1.0
C	14,850	1,400	6,015	0.7	4.3	4.3	5.3	1.0
D	18,470	1,400	9,185	0.4	4.9	4.9	5.8	0.9
E	20,380	1,400	9,025	0.4	5.0	5.0	5.9	0.9
F	22,430	1,400	7,630	0.4	5.1	5.1	6.0	0.9
G	24,210	1,400	7,335	0.4	5.2	5.2	6.1	0.9
H	26,720	900	5,400	0.5	5.4	5.4	6.3	0.9
I	30,350	900	5,060	0.4	5.6	5.6	6.6	1.0
J	32,970	700	3,795	0.4	5.7	5.7	6.7	1.0
K	35,380	600	2,945	0.4	5.9	5.9	6.9	1.0
L	40,040	600	3,090	0.0	5.9	5.9	6.9	1.0

[1]Feet above West Neck Road

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

CANAL NO. 2 WEST NECK CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
CANAL NO. 4								
A	1,560	155	600	4.1	4.1	3.0[2]	3.8	0.8
B	2,295	249	1,190	2.0	4.2	4.2	5.2	1.0
C	3,130	217	1,090	2.2	4.7	4.7	5.6	0.9
D	3,600	152	860	2.8	5.1	5.1	6.0	0.9
E	3,890	180	830	2.9	5.7	5.7	6.3	0.6
F	4,175	167	990	2.4	5.9	5.9	6.6	0.7
G	4,875	112	510	1.1	6.4	6.4	7.1	0.7
H	5,500	56	260	2.1	6.5	6.5	7.2	0.7
I	5,780	50	230	2.3	6.6	6.6	7.3	0.7
J	6,200	38	250	2.0	6.9	6.9	7.5	0.6
K	6,850	53	300	1.5	7.1	7.1	7.7	0.6
L	7,020	60	300	1.5	7.2	7.2	7.8	0.6
M	7,700	41	180	2.2	7.4	7.4	7.9	0.5
N	8,440	20	120	3.0	7.9	7.9	8.3	0.4
O	9,690	43	180	1.6	8.8	8.8	9.0	0.2

[1]Feet above confluence with Salem Canal

[2]Elevation computed without consideration of backwater effects from Salem Canal

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

CANAL NO. 4

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
CEDAR HILL CANAL								
A	3,630	52	180	1.8	7.9	5.0[2]	6.0	1.0
B	4,205	52	180	1.6	7.9	5.4[2]	6.1	0.7
C	4,580	27	100	3.1	7.9	5.8[2]	6.4	0.6
D	4,680	33	120	2.3	7.9	6.0[2]	6.5	0.5
E	5,080	40	110	2.3	7.9	7.7[2]	8.1	0.4
F	5,680	20	80	2.7	8.2	8.2	8..5	0.3
G	6,180	23	70	2.9	8.8	8.8	9.0	0.2
H	6,970	23	50	3.2	10.1	10.1	10.1	0.0
I	7,630	30	50	2.5	11.7	11.7	11.7	0.0
J	8,280	24	50	1.9	12.6	12.6	12.6	0.0
K	8,510	31	40	2.4	12.8	12.8	12.8	0.0
L	12,200	50	300	4.8	12.8	12.8	13.8	1.0
M	13,200	65	330	3.9	14.4	14.4	14.7	0.3
N	14,200	66	340	3.5	15.7	15.7	15.9	0.2

[1] Feet above confluence with Eastern Branch Elizabeth River
[2] Elevation computed without consideration of backwater effects from Eastern Branch Elizabeth River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

CEDAR HILL CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
COLONY ACRES CANAL								
A	800	179	710	2.3	6.1	6.1	7.0	0.9
B	2,025	319	1,040	1.6	7.2	7.2	8.1	0.9
C	2,868	298	930	1.7	7.4	7.4	8.3	0.9
D	3,685	212	750	2.2	8.3	8.3	9.1	0.8
E	5,127	104	560	2.9	10.1	10.1	10.5	0.4
F	5,812	70	400	4.1	10.8	10.8	11.1	0.3
G	6,542	100	650	2.5	11.9	11.9	12.4	0.5
H	7,460	79	530	3.1	12.4	12.4	13.0	0.6

[1] Feet above confluence with Canal No. 2 West Neck Creek

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

COLONY ACRES CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
FOX RUN CANAL								
A	1,210	65	230	4.0	7.9	5.8[2]	6.0	0.2
B	1,725	60	265	3.5	7.9	7.0[2]	7.1	0.1
C	2,220	57	245	3.8	7.9	7.5[2]	8.1	0.6
D	2,630	50	285	2.9	8.4	8.4	8.8	0.4
E	3,945	40	210	3.5	9.4	9.4	9.6	0.2
F	4,625	45	235	2.9	10.1	10.1	10.3	0.2
G	5,590	60	335	1.8	11.9	11.9	12.0	0.1
H	6,190	60	390	1.4	12.1	12.1	12.2	0.1

[1]Feet above confluence with Eastern Branch Elizabeth River

[2]Elevation computed without consideration of backwater effects from Eastern Branch Elizabeth River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

FOX RUN CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
GREEN RUN CANAL								
A	310	36	210	2.7	6.9	5.0[3]	5.8	0.8
B	1,035	42	220	2.6	6.9	5.4[3]	6.1	0.7
C	2,005	48	320	1.8	6.9	5.9[3]	6.5	0.6
D	2,445	36	200	2.9	6.9	6.0[3]	6.6	0.6
E	2,780	69	270	2.1	7.3	7.3	7.9	0.6
F	3,550	76	320	1.8	7.8	7.8	8.2	0.4
G	3,950	188[2]	760	1.2	8.6	8.6	8.6	0.0
H	5,572	126[2]	650	1.4	8.8	8.8	8.6	0.0
I	7,035	186[2]	830	1.1	9.1	9.1	9.1	0.0
J	7,400	150[2]	960	1.0	9.3	9.3	9.3	0.0
K	9,400	145[2]	1,010	0.9	9.5	9.5	9.5	0.0

[1]Feet above confluence with Canal No. 2 London Bridge Creek

[2]Storage-type analysis

[3]Elevation computed without consideration of backwater effects from Eastern Branch Lynnhaven River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

GREEN RUN CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
HOLLAND ROAD CORRIDOR SYSTEM								
A	4,600	117	740	0.5	6.9	5.8[2]	6.3	0.5
B	6,990	96	510	0.8	6.9	6.6[2]	7.1	0.5
C	7,290	107	620	0.6	7.5	7.5	8.0	0.5
D	8,805	112	960	0.4	8.0	8.0	8.5	0.5

[1]Feet above confluence with Green Run Canal

[2]Elevation computed without consideration of backwater effects from Eastern Branch Lynnhaven River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

HOLLAND ROAD CORRIDOR SYSTEM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
HOLLAND ROAD TRIBUTARY THALIA CREEK								
A	587	30	250	4.2	9.4	6.4[2]	7.1	0.8
B	1,392	40	180	5.3	9.4	7.0[2]	7.6	0.6
C	1,624	60	430	2.1	10.7	10.7	10.7	0.0
D	2,860	250	1,650	0.5	10.8	10.8	10.8	0.0
E	3,284	70	430	1.7	11.7	11.7	11.7	0.0

[1]Feet above confluence with Left Bank Tributary Thalia Creek

[2]Elevation computed without consideration of backwater effects from Left Bank Tributary Thalia Creek

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

HOLLAND ROAD TRIBUTARY THALIA CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
LAKE BANBURY								
A	5,545	242	1,200	0.6	7.9	7.9	7.9	0.0
B	5,953	173	850	0.6	7.9	7.9	7.9	0.0
C	6,110	124	600	0.8	8.0	8.0	8.3	0.3
D	6,650	110	609	0.0	11.6	11.6	11.6	0.0

[1]Feet above confluence with Eastern Branch Elizabeth River

[2]Storage-type analysis

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

LAKE BANBURY

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
LEFT BANK TRIBUTARY THALIA CREEK								
A	785	62	335	4.9	6.9	6.4[2]	7.4	1.0
B	1,285	60	460	3.4	7.2	7.2	7.9	0.7
C	2,870	66	350	4.1	8.1	8.1	8.6	0.5
D	4,615	100	795	1.6	9.4	9.4	9.7	0.3
E	5,445	84	445	2.7	9.4	9.4	9.7	0.3

[1] Feet above confluence with Thalia Creek
[2] Elevation computed without consideration of backwater effects from Thalia Creek

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

LEFT BANK TRIBUTARY THALIA CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY[3]	WITH FLOODWAY	INCREASE
PINE TREE BRANCH								
A	2,150	186	130	1.8	7.9	3.1	4.1	1.0
B	2,710	180[2]	990	0.4	7.9	6.8	6.8	0.0
C	3,660	188[2]	700	0.6	7.9	6.9	6.9	0.0
D	4,790	209[2]	480	0.9	7.9	7.2	7.2	0.0

[1] Feet above confluence with Eastern Branch Lynnhaven River
[2] Storage-type analysis
[3] Elevation computed without consideration of backwater effects from Eastern Branch Lynnhaven River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

PINE TREE BRANCH

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
SALEM CANAL								
A	300	763	3,100	0.7	3.0	3.0	4.0	1.0
B	900	620	2,810	0.8	4.0	4.0	4.6	0.6
C	2,250	510	2,140	1.0	4.3	4.3	4.9	0.6
D	4,200	490	2,220	0.9	4.7	4.7	5.3	0.6
E	5,540	540	2,850	0.7	4.8	4.8	5.6	0.8
F	7,098	537	2,690	0.7	4.9	4.9	5.7	0.8
G	7,975	410	2,150	0.8	4.9	4.9	5.8	0.9
H	9,228	349	1,740	1.0	5.1	5.1	6.0	0.9
I	10,736	380	2,050	0.8	5.3	5.3	6.2	0.9
J	11,955	380	1,840	0.8	5.7	5.7	6.7	1.0
K	13,520	300	1,450	0.8	5.7	5.7	6.7	1.0
L	14,735	300	1,150	0.9	5.9	5.9	6.9	1.0
M	16,437	300	1,150	0.8	6.3	6.3	7.2	0.9
N	17,110	119[2]	350	2.3	6.5	6.5	7.3	0.8
O	18,279	100	460	1.4	7.4	7.4	8.2	0.8
P	19,210	100	560	1.0	7.6	7.6	8.4	0.8
Q	20,200	100	610	0.9	7.7	7.7	8.5	0.8
R	21,475	100	340	1.3	8.1	8.1	8.7	0.6
S	22,480	108[2]	240	1.7	8.3	8.3	9.1	0.8
T	23,304	105[2]	280	1.2	8.5	8.5	9.3	0.8
U	24,075	61	320	0.9	8.6	8.6	9.4	0.8

[1]Feet above Indian River Road
[2]Floodway width adjusted to updated waterlines, does not match model

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

SALEM CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
THALIA CREEK								
A	1,900	70	470	2.8	6.9	3.6[2]	4.4	0.8
B	2,795	98	560	2.3	6.9	4.1[2]	5.0	0.9
C	3,840	44	290	4.5	6.9	4.9[2]	5.8	0.9
D	4,515	357	1,050	1.2	6.9	6.8[2]	6.8	0.0
E	6,695	86	566	2.0	6.9	6.9	6.9	0.0
F	8,527	98	647	1.8	7.5	7.5	7.5	0.0

[1] Feet above Norfolk and Southern Railroad
[2] Elevation computed without consideration of backwater effects from Lynnhaven River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

FLOODWAY DATA

THALIA CREEK

5.0 INSURANCE APPLICATION

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. These zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or base flood depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone AR

Zone AR is the flood insurance risk zone that corresponds to an area of special flood hazard formerly protected from the 1-percent-annual-chance flood event by a flood-control system that was subsequently decertified. Zone AR indicates that the former flood-control system is being restored to provide protection from the 1-percent-annual-chance or greater flood event.

Zone A99

Zone A99 is the flood insurance zone that corresponds to areas of the 1-percent-annual-chance floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No BFEs or depths are shown within this zone.

Zone V

Zone V is the flood insurance rate zone that corresponds to the 1-percent-annual-chance coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no BFEs are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent-annual-chance floodplain, areas within the 0.2-percent-annual-chance floodplain, areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance flood by levees. No BFEs or depths are shown within this zone.

Zone X (Future Base Flood)

Zone X (Future Base Flood) is the flood insurance risk zone that corresponds to the 1-percent-annual-chance floodplains that are determined based on future-conditions hydrology. No BFEs or base flood depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent-annual-chance floodplains that were studied by detailed methods, shows selected whole-foot BFEs or average depths. Insurance agents use the zones and BFEs in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent-annual-chance floodplains, floodways and the locations of selected cross sections used in the hydraulic analyses and floodway computations.

7.0 OTHER STUDIES

A floodplain information report for the City of Virginia Beach was prepared by the USACE in July 1969 (Reference 5). A number of other reports have been prepared by the Norfolk District of the USACE concerning flooding in Virginia Beach, including a feasibility report for beach erosion control and hurricane protection, a feasibility report for flood control and navigation, and a study of Canal No. 2 (References 17-21). FEMA requested that the National Oceanic and Atmospheric Administration study flood levels from storm tides on the open coasts of Virginia, Maryland and Delaware. This study was completed in August 1976 (Reference 22).

Flood Insurance Studies (FIS) have been prepared for the Cities of Norfolk and Chesapeake, Virginia; and the Unincorporated Areas of Currituck County, North Carolina (References 23-25).

Because it is based on more up-to-date analyses, this FIS supersedes the previously printed FIS for the City of Virginia Beach (Reference 26).

8.0 LOCATION OF DATA

Information concerning the pertinent data used in preparation of this FIS can be obtained by contacting FEMA, Federal Insurance and Mitigation Division, FEMA Region III, One Independence Mall, Sixth Floor, 615 Chestnut Street, Philadelphia, Pennsylvania 19106-4404.

9.0 BIBLIOGRAPHY AND REFERENCES

1. LIDAR collected for the City of Virginia Beach, delivered by: Sanborn, Colorado Springs, Colorado, June 2005, CGIS_OWNER.TOPO_Contours.

2. Commonwealth of Virginia, Virginia Base Map Program Orthophotography – 2009 (NAD83 HARN), Richmond, Virginia, 2010.

3. U.S. Census Bureau (2010). State & County Quickfacts: City of Virginia Beach, Virginia. Retrieved April 1, 2013, from http://quickfacts.census.gov.

4. State of Virginia, Division of State Planning and Community Affairs. Data Summary – City of Virginia Beach, Richmond, Virginia, April 1973.

5. U.S. Army Corps of Engineers, Norfolk District. Flood Plain Information Report, Coastal Flooding, Virginia Beach, Virginia, Norfolk, Virginia, July 1969.

6. U.S. Department of Commerce, Weather Bureau, Technical Paper No. 40. Rainfall Frequency Atlas of the United States, Washington, D.C., 1961, Revised 1963.

7. Mid States Engineering, Inc. Topographic Maps of the City of Virginia Beach, Virginia, Scale 1:2,400, Contour Interval 2 Feet, Indianapolis, Indiana, March 1986.

8. Raytheon Company, Automertic Operation. City of Virginia Beach, Virginia

Topographic Maps, Scale 1:2,400, Contour Intervals 2 Feet, Wayland, Massachusetts.

9. U.S. Army Corps of Engineers, Hydrologic Engineering Center. HEC-2 Water Surface Profiles, User Manual, Davis, California, September 1990.

10. U.S. Army Corps of Engineers, Galveston District. Guidelines for Identifying Coastal High Hazard Zones, Galveston, Texas, June 1975.

11. National Academy of Sciences. Methodology for Calculating Wave Action Effects Associated with Storm Surges, Washington, D.C. 1977.

12. Federal Emergency Management Agency. Procedures for Applying Marsh Grass Methodology, Draft, October 1984.

13. Luettich, R. A. and J.J Westerink. A (Parallel) Advanced Circulation Model for Oceanic, Coastal and Estuarine Waters (ADCIRC). Version 45.12. February 6, 2008. University of North Carolina at Chapel Hill, Institute of Marine Sciences. Morehead City, North Carolina.

14. U.S. Army Corps of Engineers. ERDC/CHL TR11-X. FEMA Region 3 Storm Surge Study Coastal Storm Surge Analysis: Modeling System Validation Submission No. 2. U.S. Army Corps of Engineers, 2012.

15. Federal Emergency Management Agency. Atlantic Ocean and Gulf of Mexico Update Coastal Guidelines Update. Washington, D.C., 2007.

16. Federal Emergency Management Agency. Wave Height Analysis for Flood Insurance Studies (WHAFIS), Version 4.0. Washington, D.C., August 2007.

17. City of Virginia Beach, Virginia, Charlestowne Lakes South Flood Study. December 1988.

18. Camp, Dresser & McKee. City of Virginia Beach Department of Public Works, Stormwater Management Plan, Watershed 12 – Stumpy Lake, December 1987.

19. U.S. Army Corps of Engineers, Norfolk District. Virginia Beach, Virginia, Feasibility Report for Beach Erosion Control and Hurricane Protection, Norfolk, Virginia, September 1970.

20. U.S. Army Corps of Engineers, Norfolk District. Virginia Beach Streams, Feasibility Report for Flood Control and Navigation, Virginia Beach, Virginia, Norfolk, Virginia, July 1975.

21. U.S. Army Corps of Engineers, Norfolk District. Virginia Beach, Streams, Canal Number Two, General Design Memorandum, Phase I, Virginia Beach, Virginia, Norfolk, Virginia, September 1980.

22. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NWS HYDRO-32, Storm Tide Frequency Analysis for

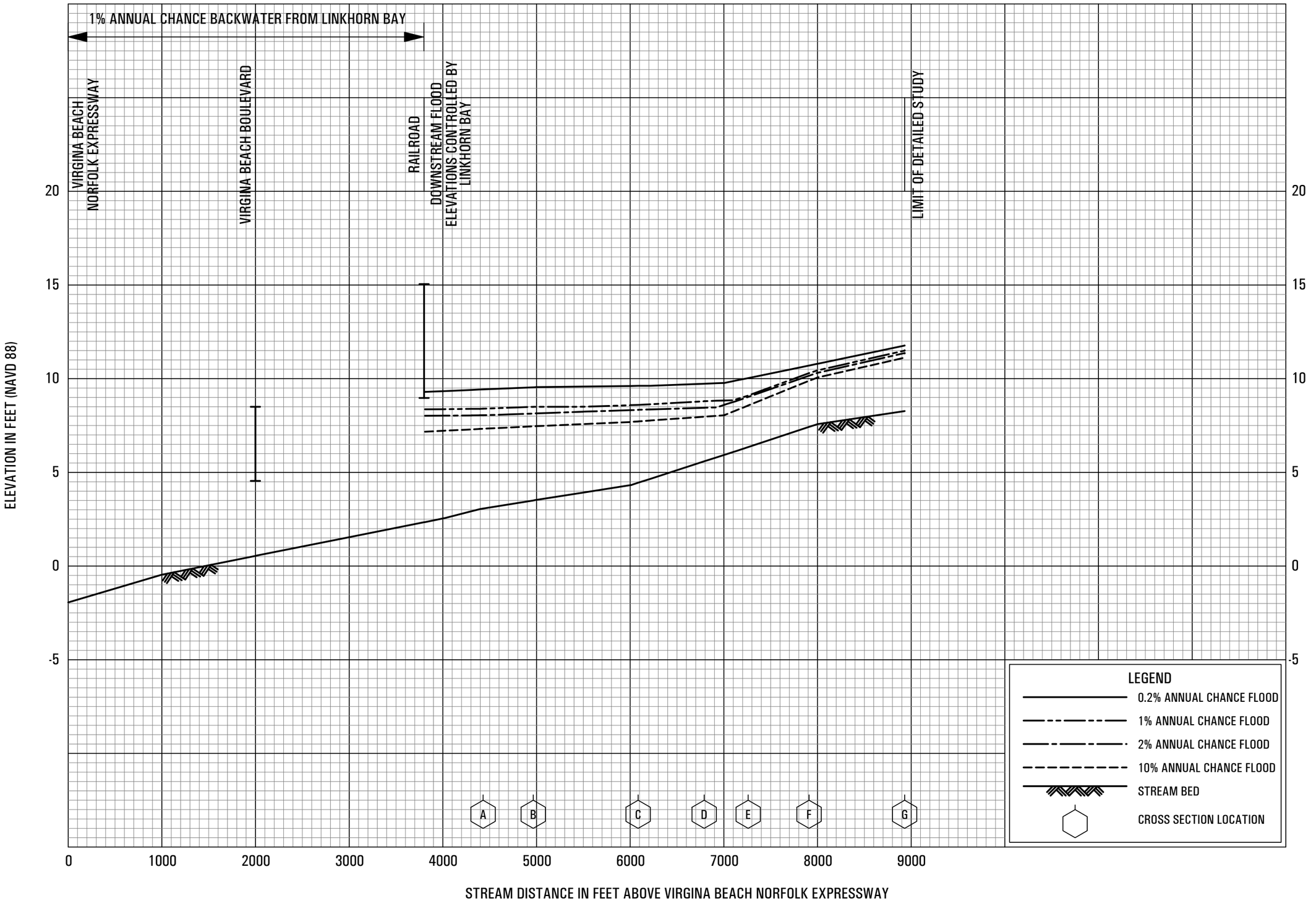
the Open Coast of Virginia, Maryland and Delaware, Silver Springs, Maryland, August 1976.

23. Federal Emergency Management Agency. Flood Insurance Study, City of Norfolk, Virginia, Independent City, Washington, D.C., Study underway.

24. Federal Emergency Management Agency. Flood Insurance Study, City of Chesapeake, Virginia, Independent City, Washington, D.C., Study underway.

25. Federal Emergency Management Agency. Flood Insurance Study, Currituck County, North Carolina and Incorporated Areas, Washington, D.C., December 16, 2005.

26. Federal Emergency Management Agency. Flood Insurance Study, City of Virginia Beach, Virginia, Independent City, Washington, D.C., May 4, 2009.



FLOOD PROFILES

CANAL NO.1 NORTH

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA

(INDEPENDENT CITY)

01P

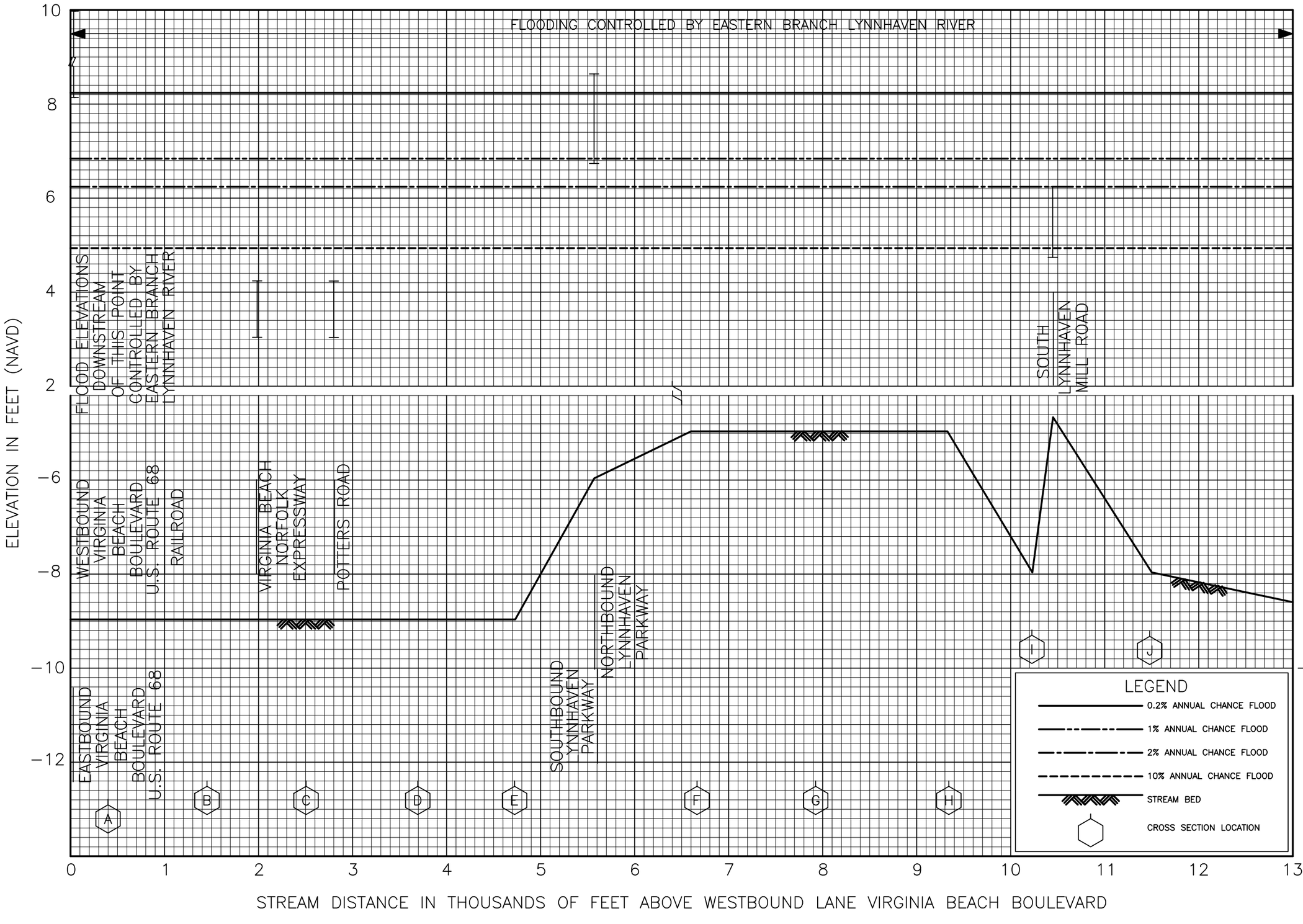
FLOOD PROFILES

CANAL NO.2 LONDON BRIDGE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

02P



FLOODING CONTOLLED BY EASTERN BRANCH LYNNHAVEN RIVER

ELEVATION IN FEET (NAVD)

STREAM DISTANCE IN THOUSANDS OF FEET ABOVE WESTBOUND LANE VIRGINIA BEACH BOULEVARD

BOW CREEK BOULEVARD

LYNNHAVEN PARKWAY

CONFLUENCE OF GREEN RUN CANAL

SHIPPS CORNER ROAD

K L M N O P

LEGEND

- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

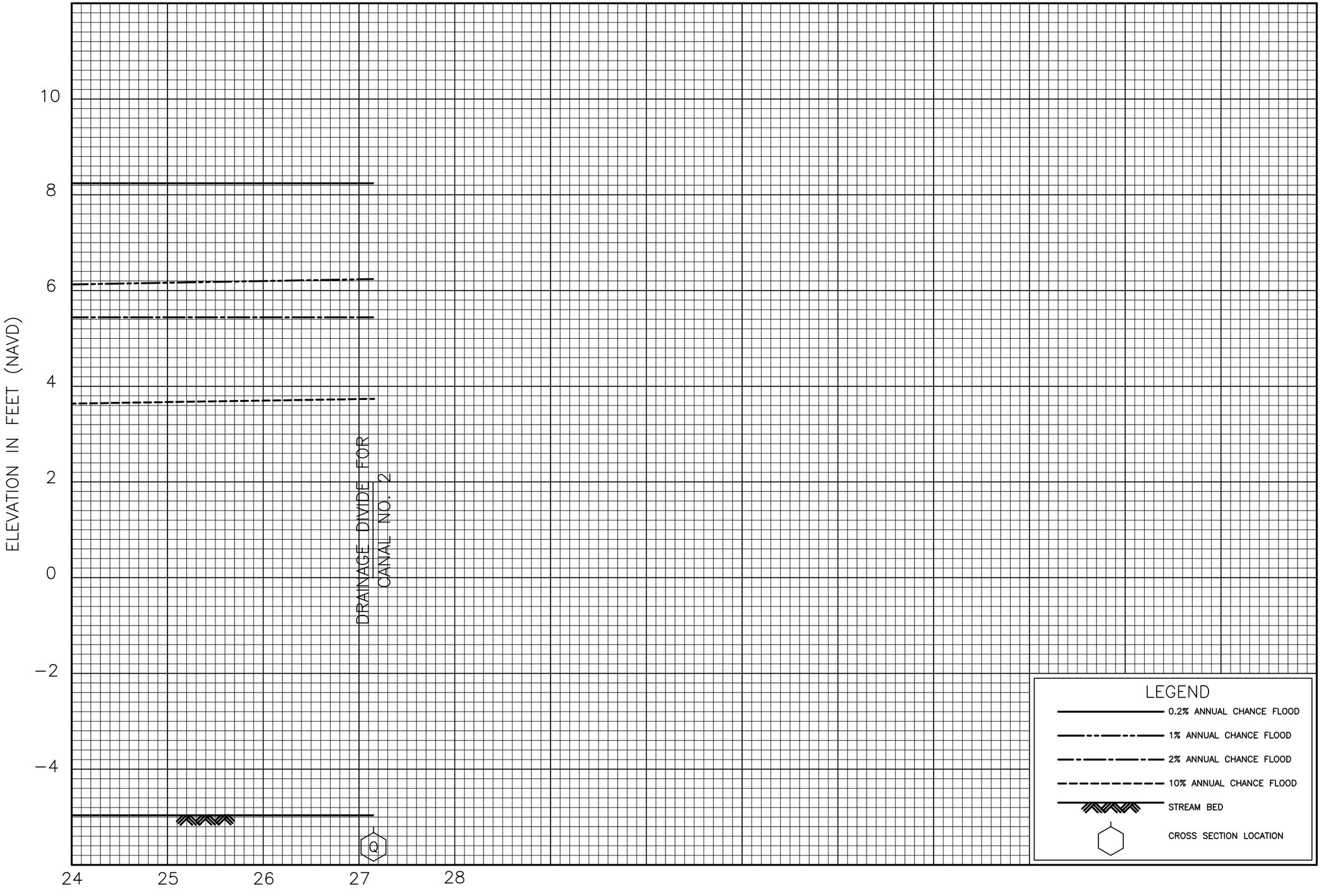
FLOOD PROFILES

CANAL NO.2 LONDON BRIDGE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

03P



FLOOD PROFILES

CANAL NO.2 LONDON BRIDGE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

04P

BACKWATER EFFECTS FROM BACK BAY

WEST NECK ROAD

INDIAN RIVER ROAD

ELEVATION IN FEET (NAVD)

10
8
6
4
2
0
0.2
−5
−6
−8
−10

DOWNSTREAM FLOOD ELEVATIONS CONTROLLED BY BACK BAY

LEGEND

- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

A

B

0 1 2 3 4 5 6 7 8 9 10 11 12 13

STREAM DISTANCE IN THOUSANDS OF FEET ABOVE WEST NECK ROAD

FLOOD PROFILES

CANAL NO.2 WEST NECK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

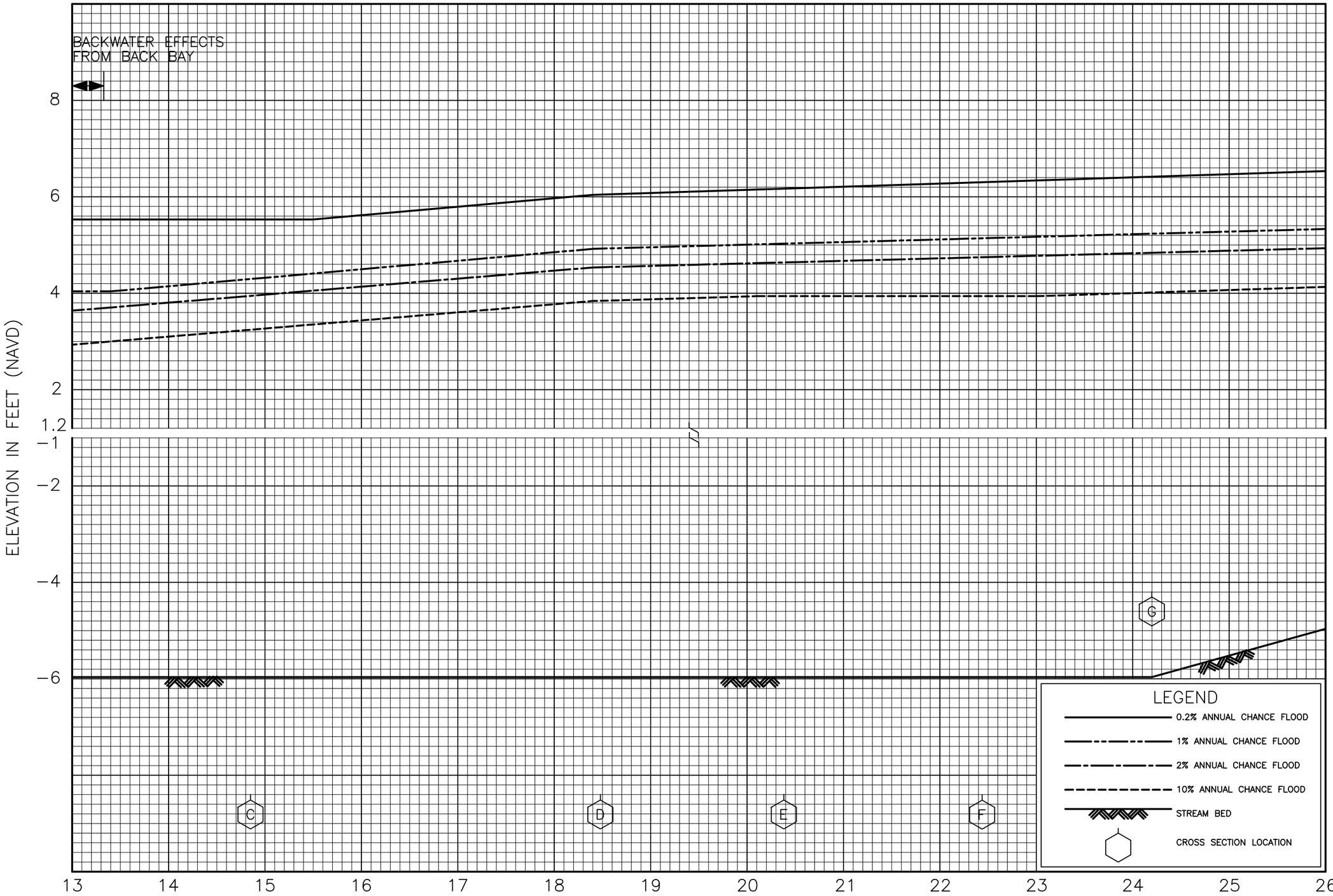
CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

05P

FLOOD PROFILES

CANAL NO.2 WEST NECK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)



ELEVATION IN FEET (NAVD)

PRINCESS ANNE ROAD

CONFLUENCE OF COLONY ACRES CANAL

10
8
6
4
3.2
−1
−2
−4
−6
−8

H
I
J
K

LEGEND

- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

26 27 28 29 30 31 32 33 34 35 36 37

STREAM DISTANCE IN THOUSANDS OF FEET ABOVE WEST NECK ROAD

FLOOD PROFILES

CANAL NO.2 WEST NECK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

07P

ELEVATION IN FEET (NAVD)

12
10
8
6
4
2
0
−2
−4

DRAINAGE DIVIDED FOR CANAL NO. 2

37
38
39
40
41

STREAM DISTANCE IN THOUSANDS OF FEET ABOVE WEST NECK ROAD

LEGEND

- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

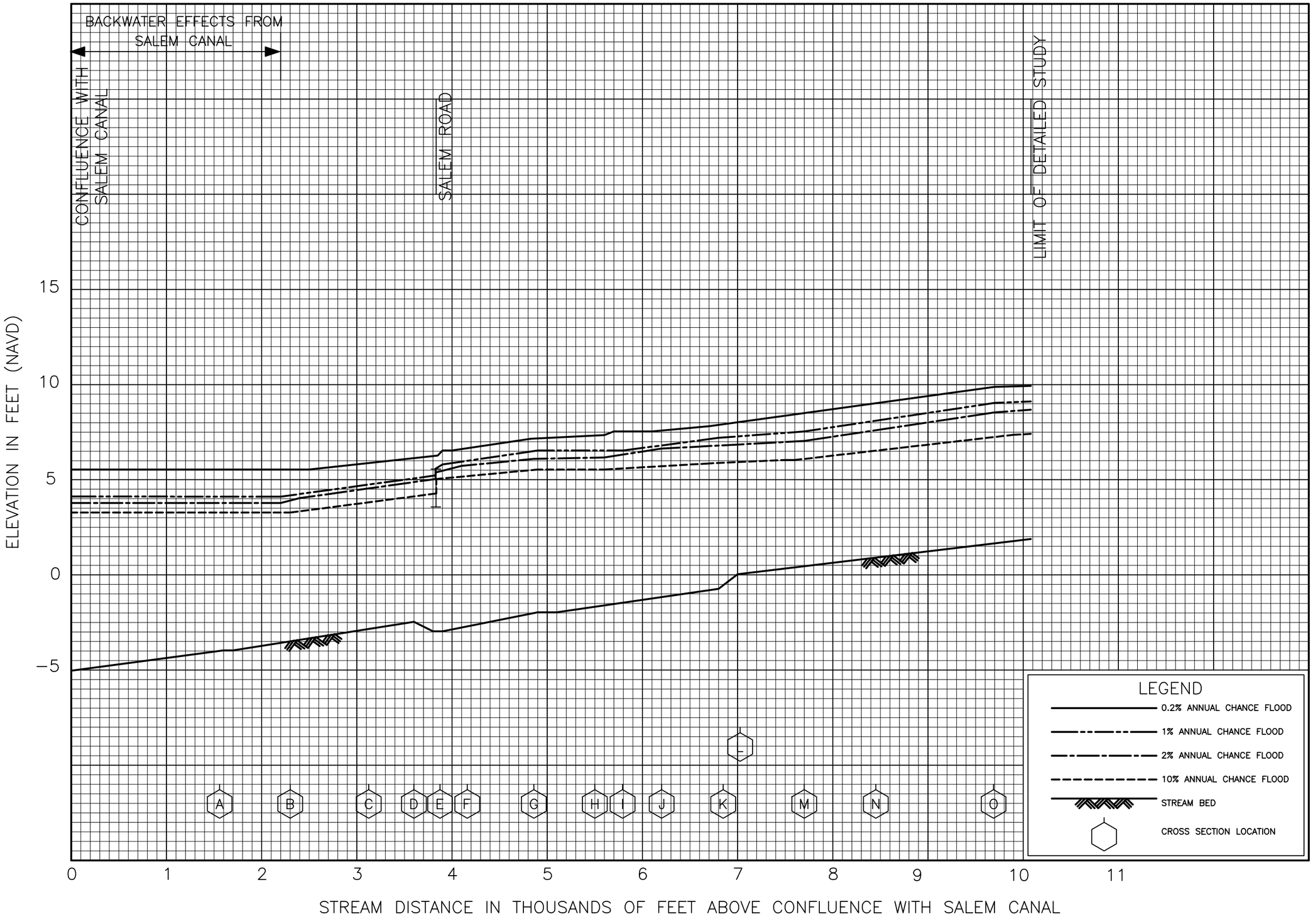
FLOOD PROFILES

CANAL NO.2 WEST NECK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

08P



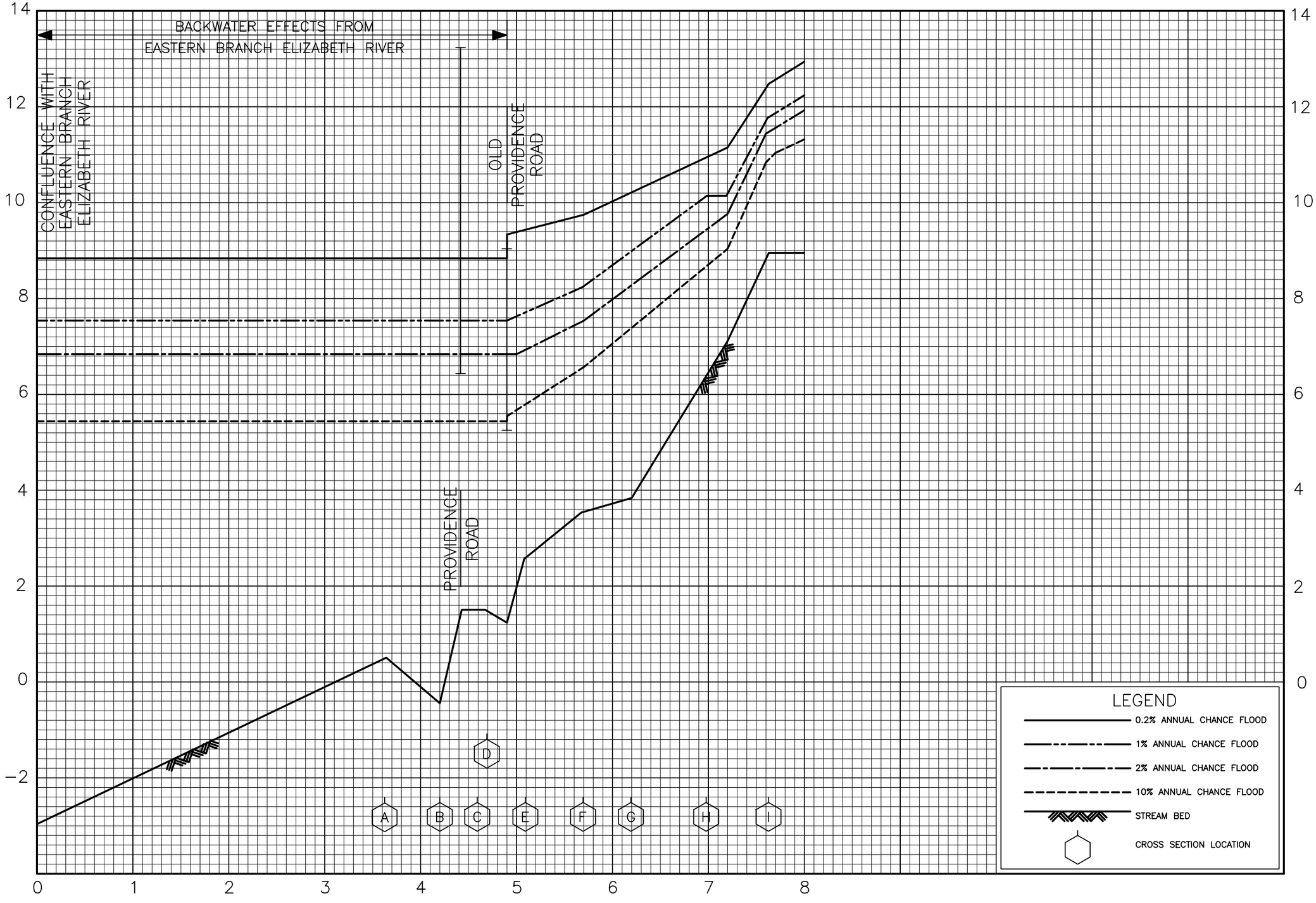
FLOOD PROFILES

CANAL NO.4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

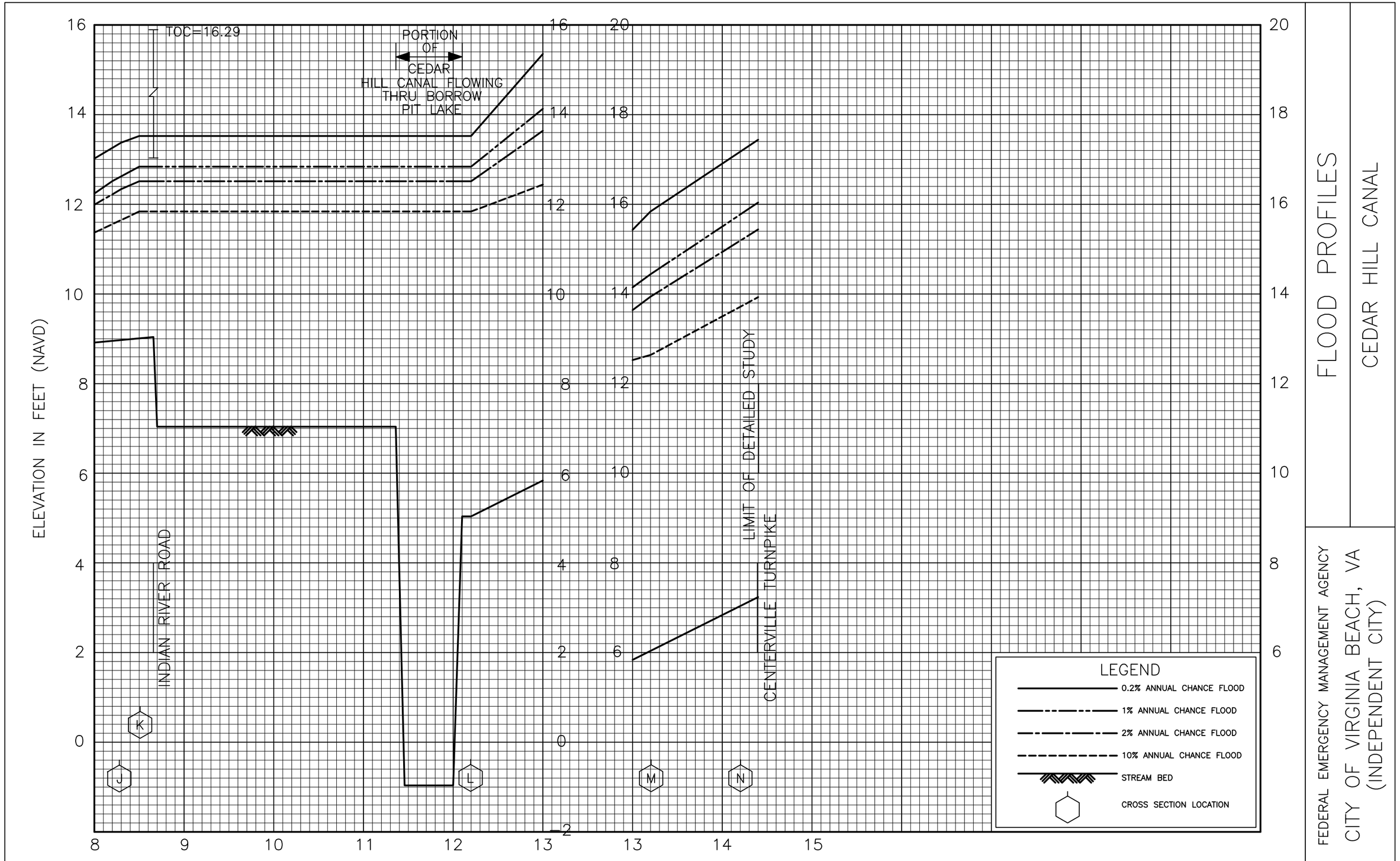
09P



FLOOD PROFILES

CEDAR HILL CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY
CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

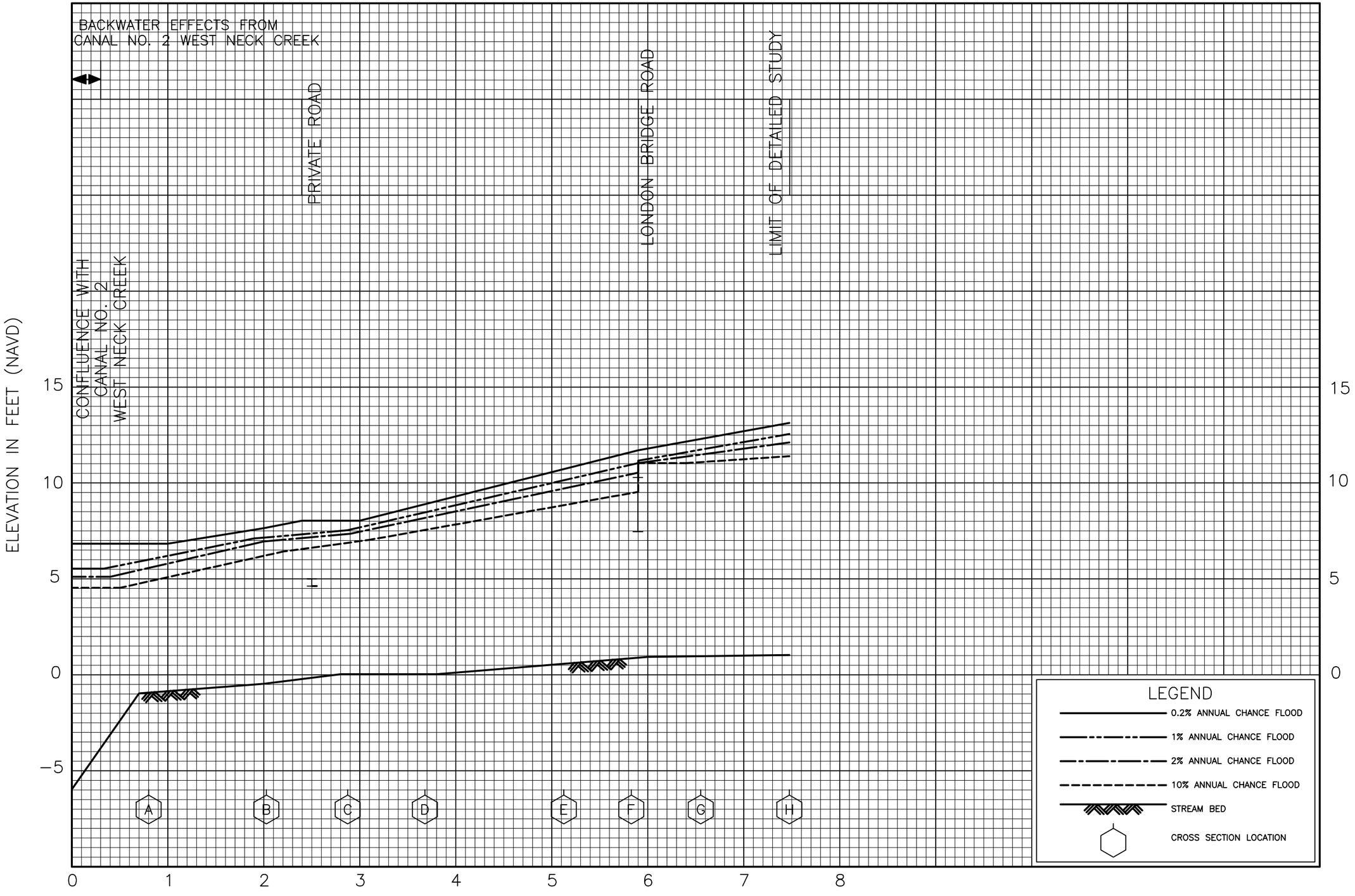


FLOOD PROFILES

CEDAR HILL CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

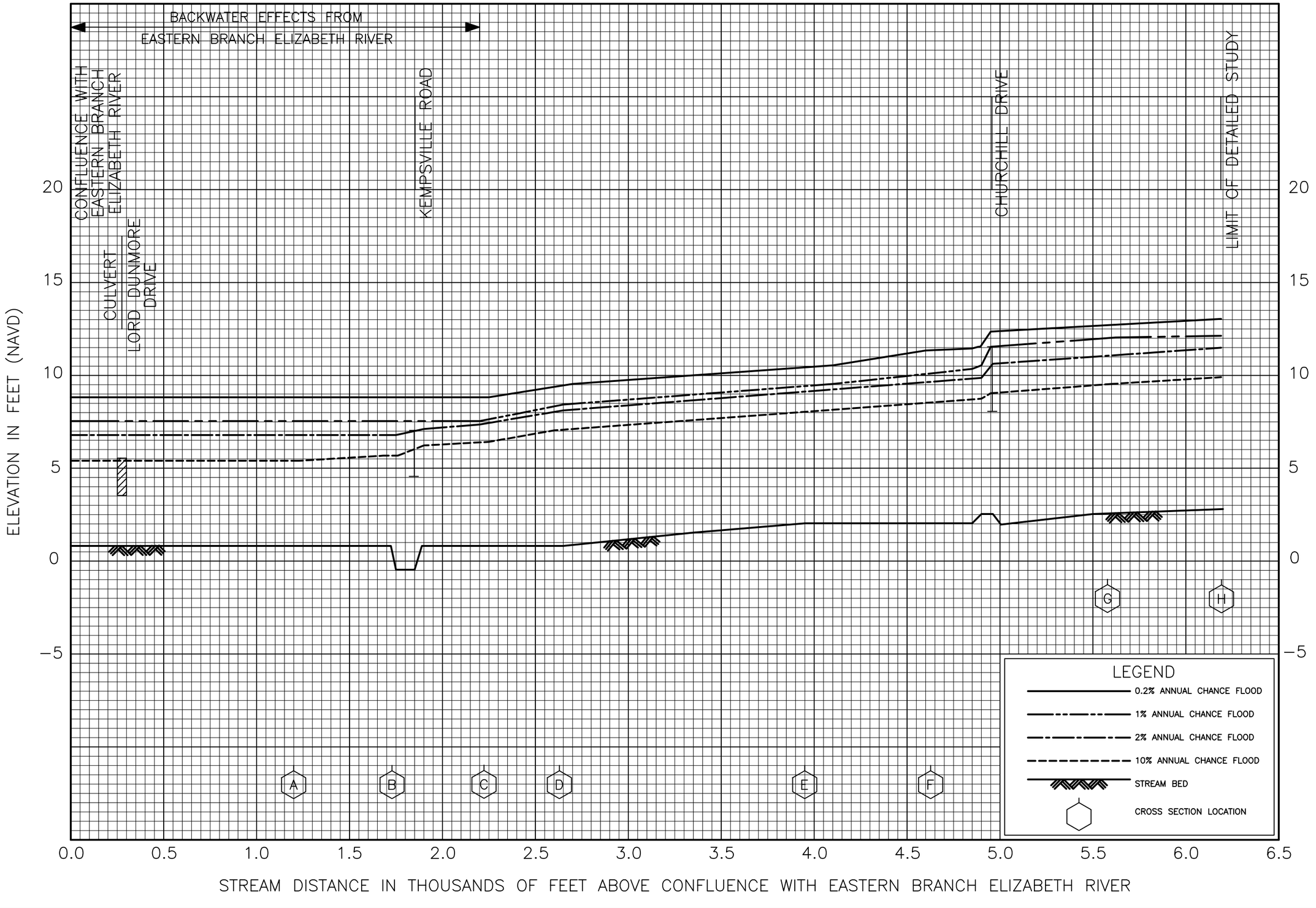


FLOOD PROFILES

COLONY ACRES CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY
CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

12P



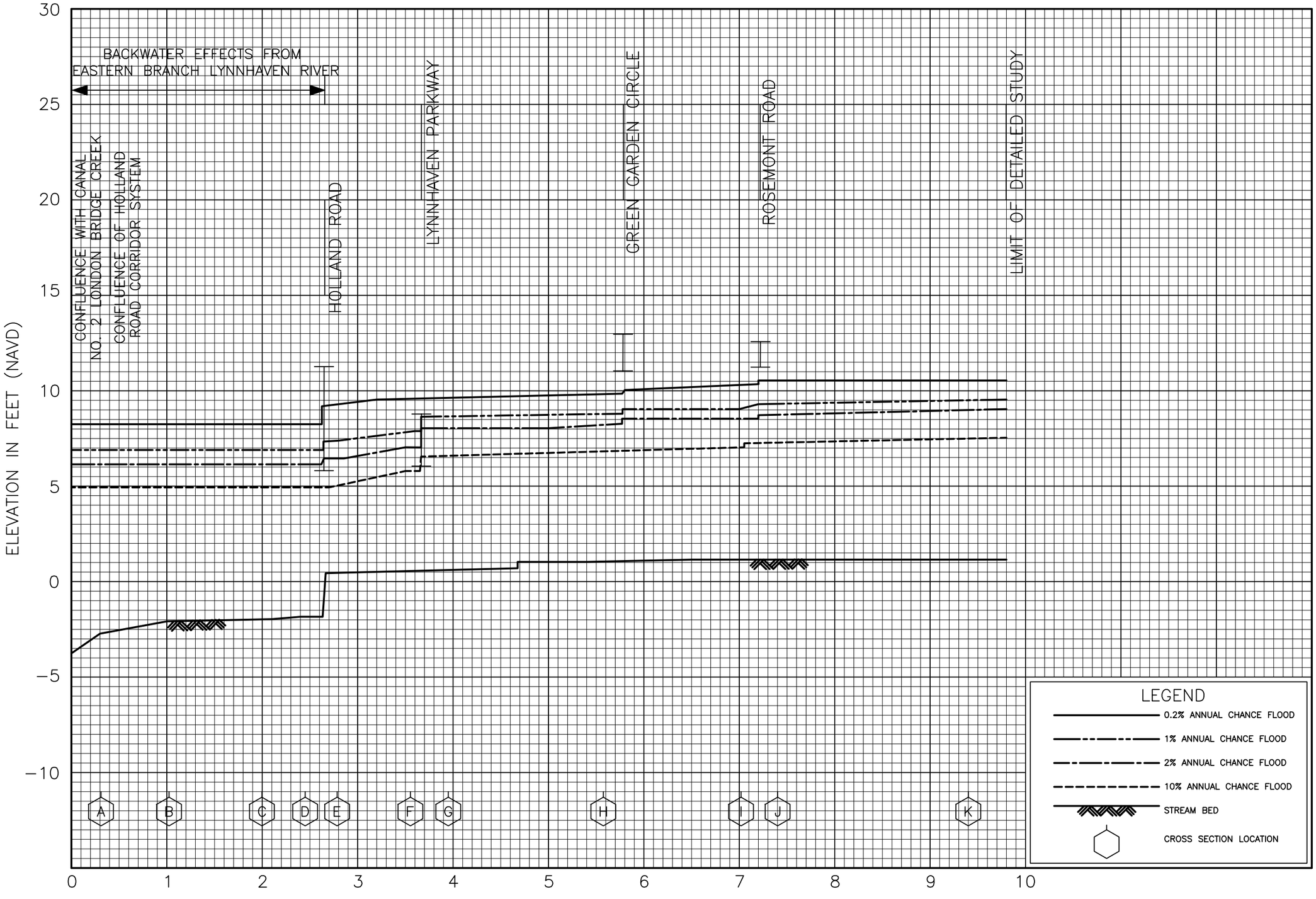
FLOOD PROFILES

FOX RUN CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

13P

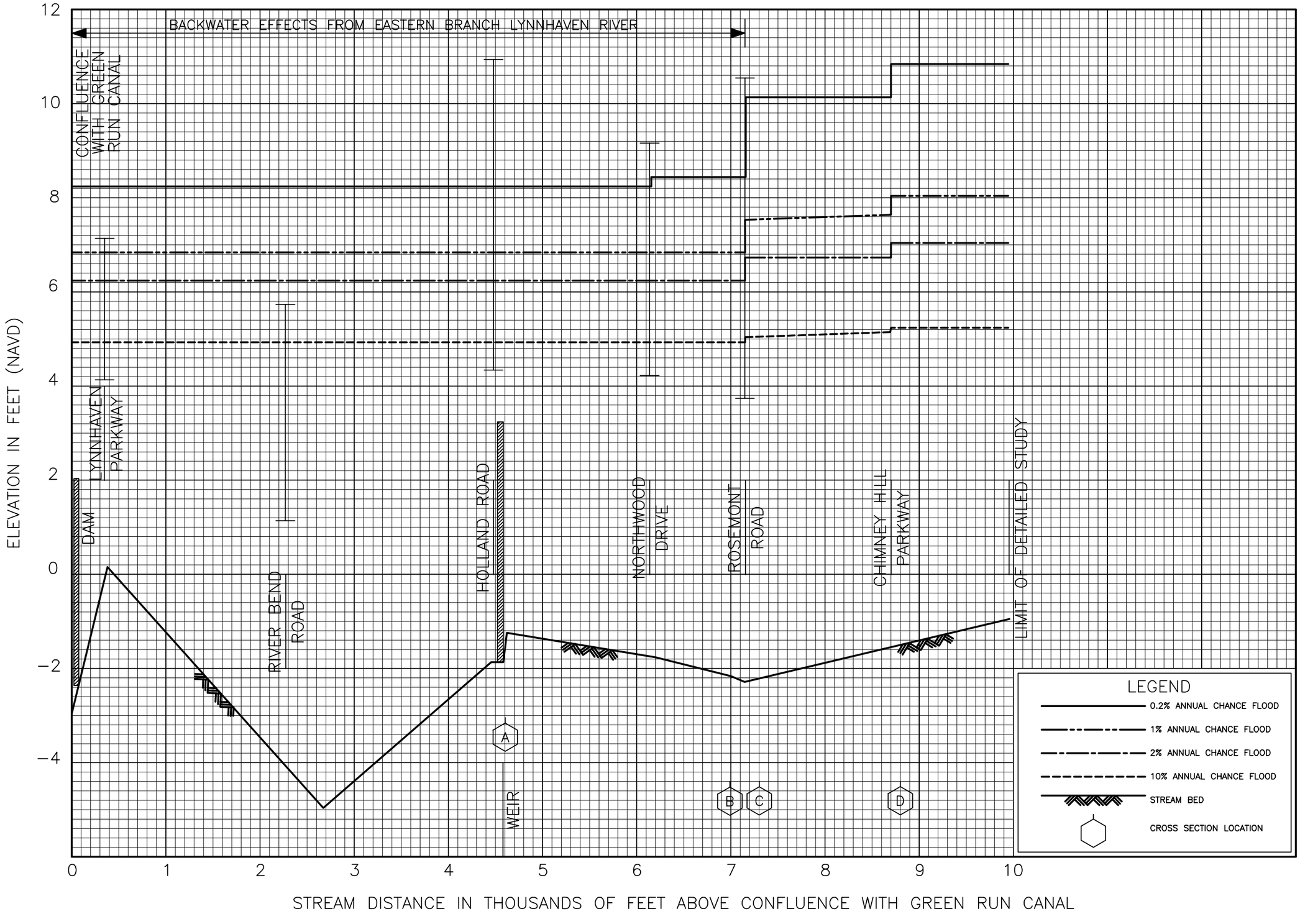


FLOOD PROFILES

GREEN RUN CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

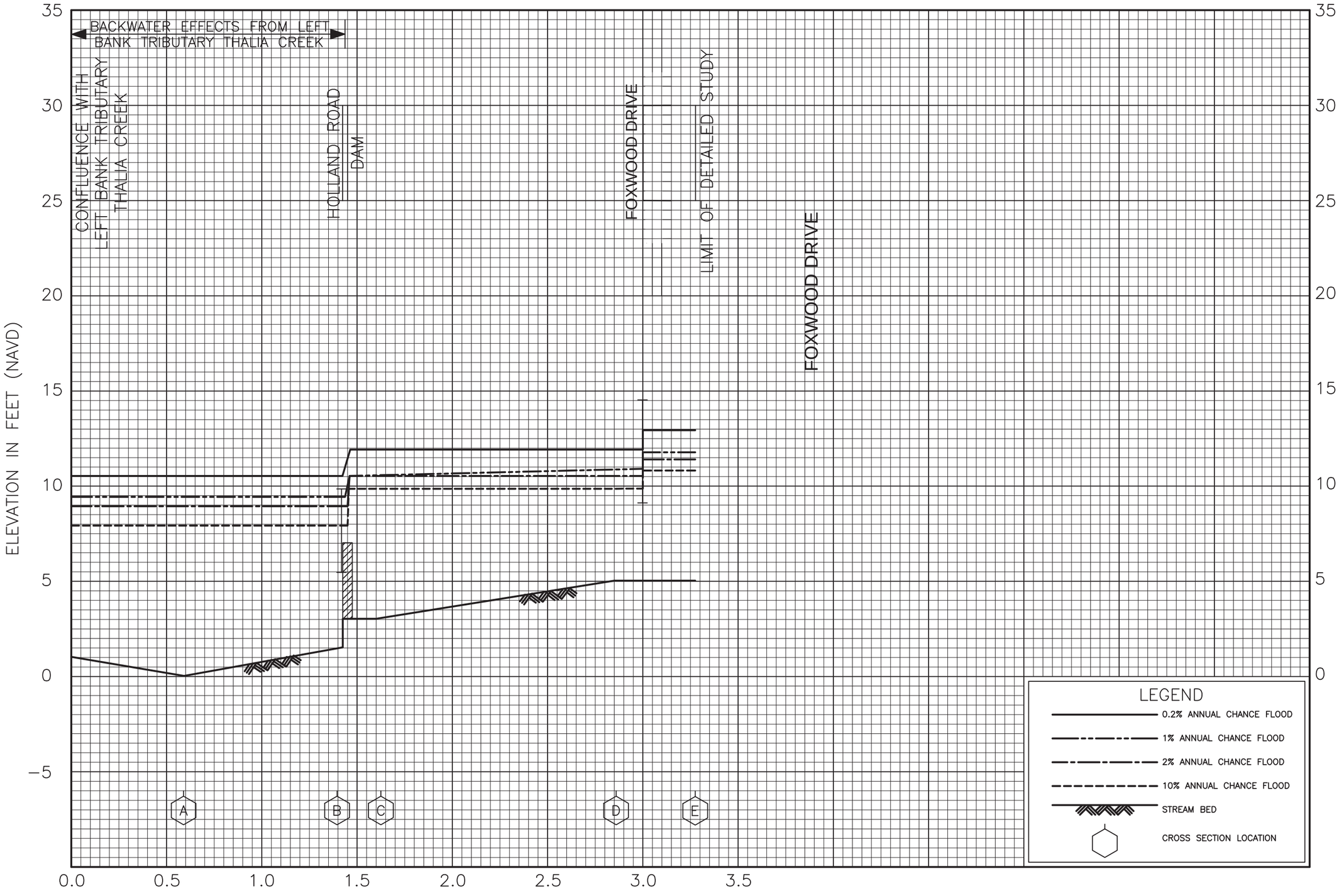


FLOOD PROFILES

HOLLAND ROAD CORRIDOR SYSTEM

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

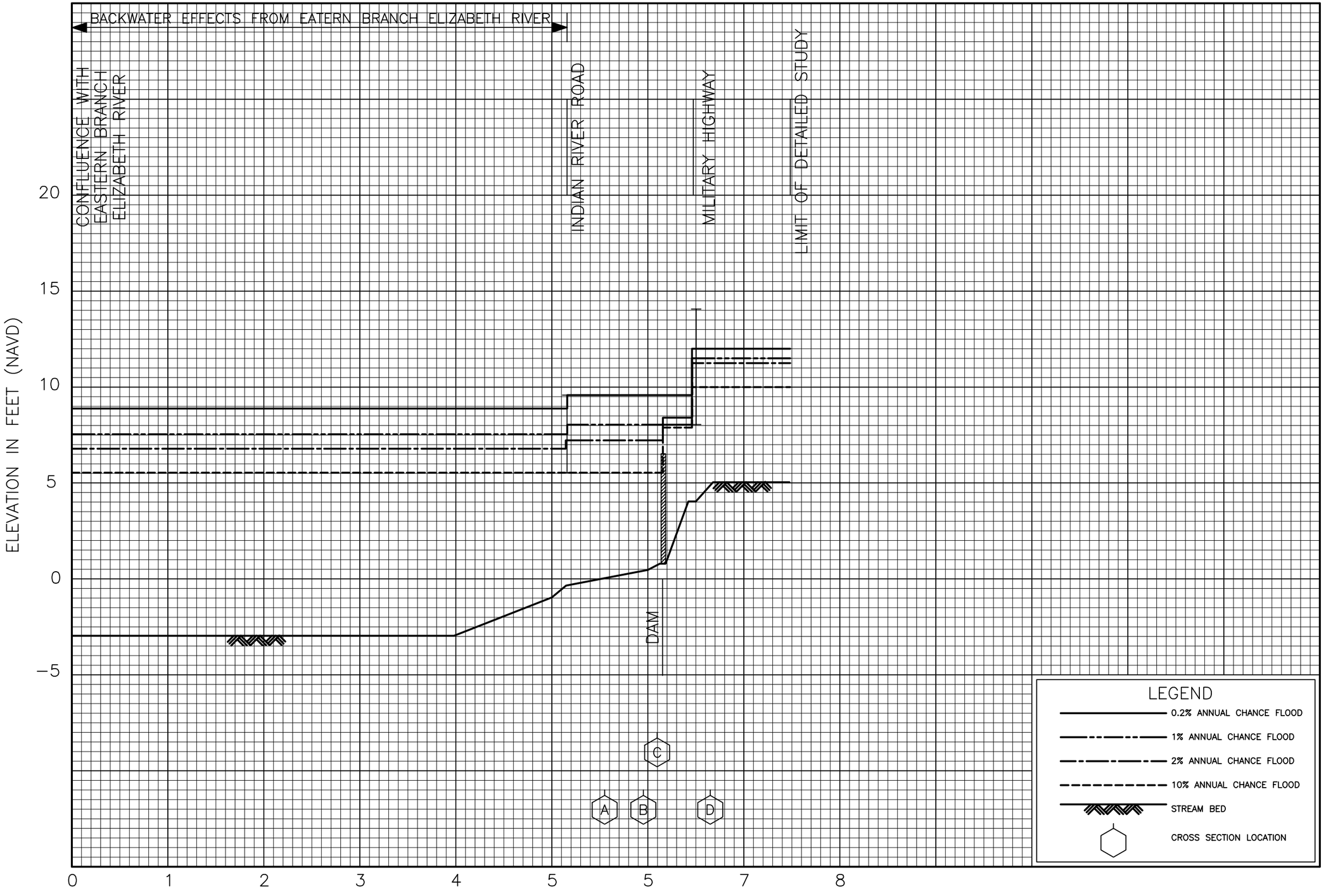


FLOOD PROFILES

HOLLAND ROAD TRIBUTARY THALIA CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)



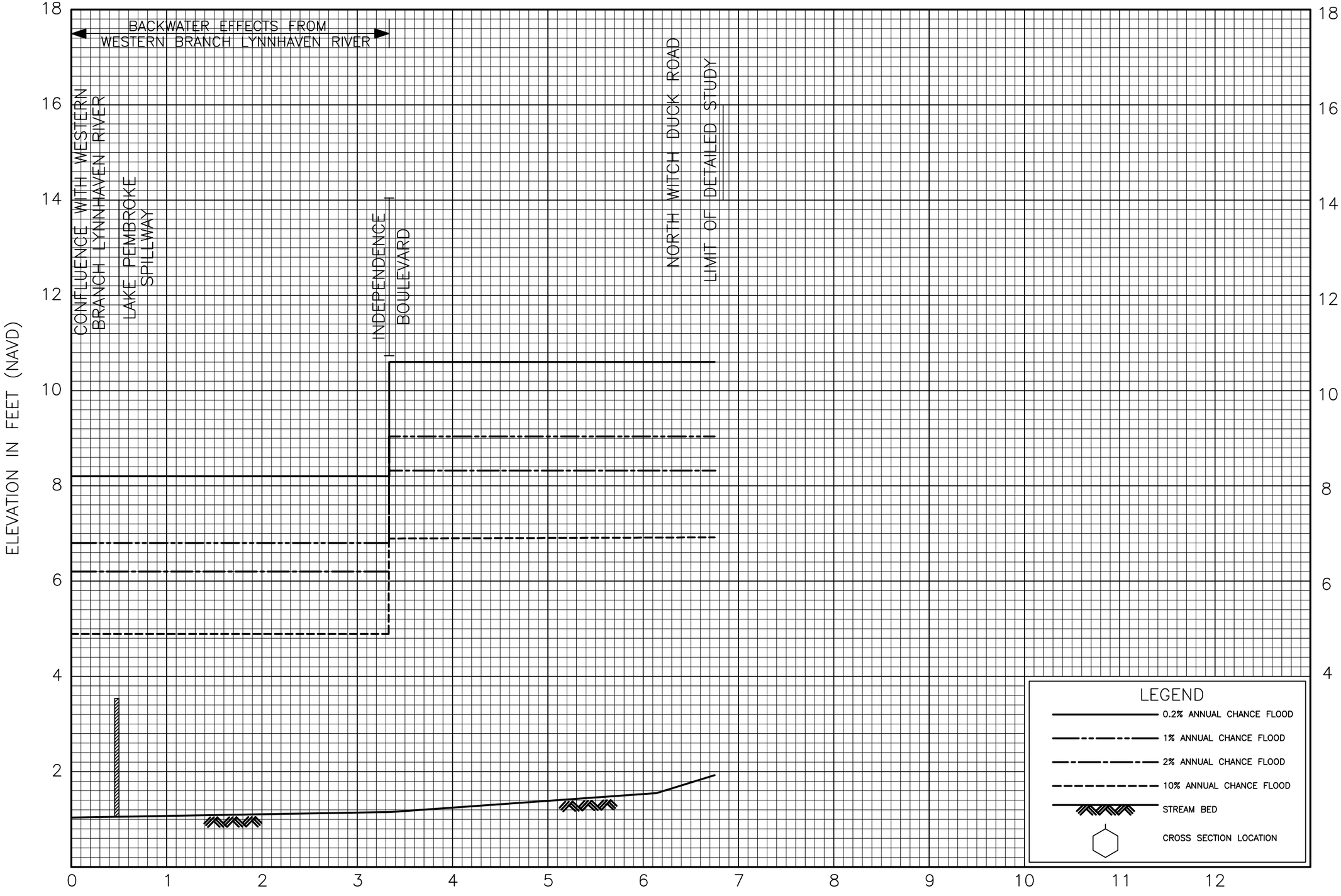
FLOOD PROFILES

LAKE BANBURY

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

17P


BACKWATER EFFECTS FROM WESTERN BRANCH LYNNHAVEN RIVER
CONFLUENCE WITH WESTERN BRANCH LYNNHAVEN RIVER
LAKE PEMBROKE SPILLWAY
INDEPENDENCE BOULEVARD
NORTH WITCH DUCK ROAD
LIMIT OF DETAILED STUDY
ELEVATION IN FEET (NAVD)
STREAM DISTANCE IN THOUSANDS OF FEET ABOVE CONFLUENCE WITH WESTERN BRANCH LYNNHAVEN RIVER
LEGEND
0.2% ANNUAL CHANCE FLOOD
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD
10% ANNUAL CHANCE FLOOD
STREAM BED
CROSS SECTION LOCATION

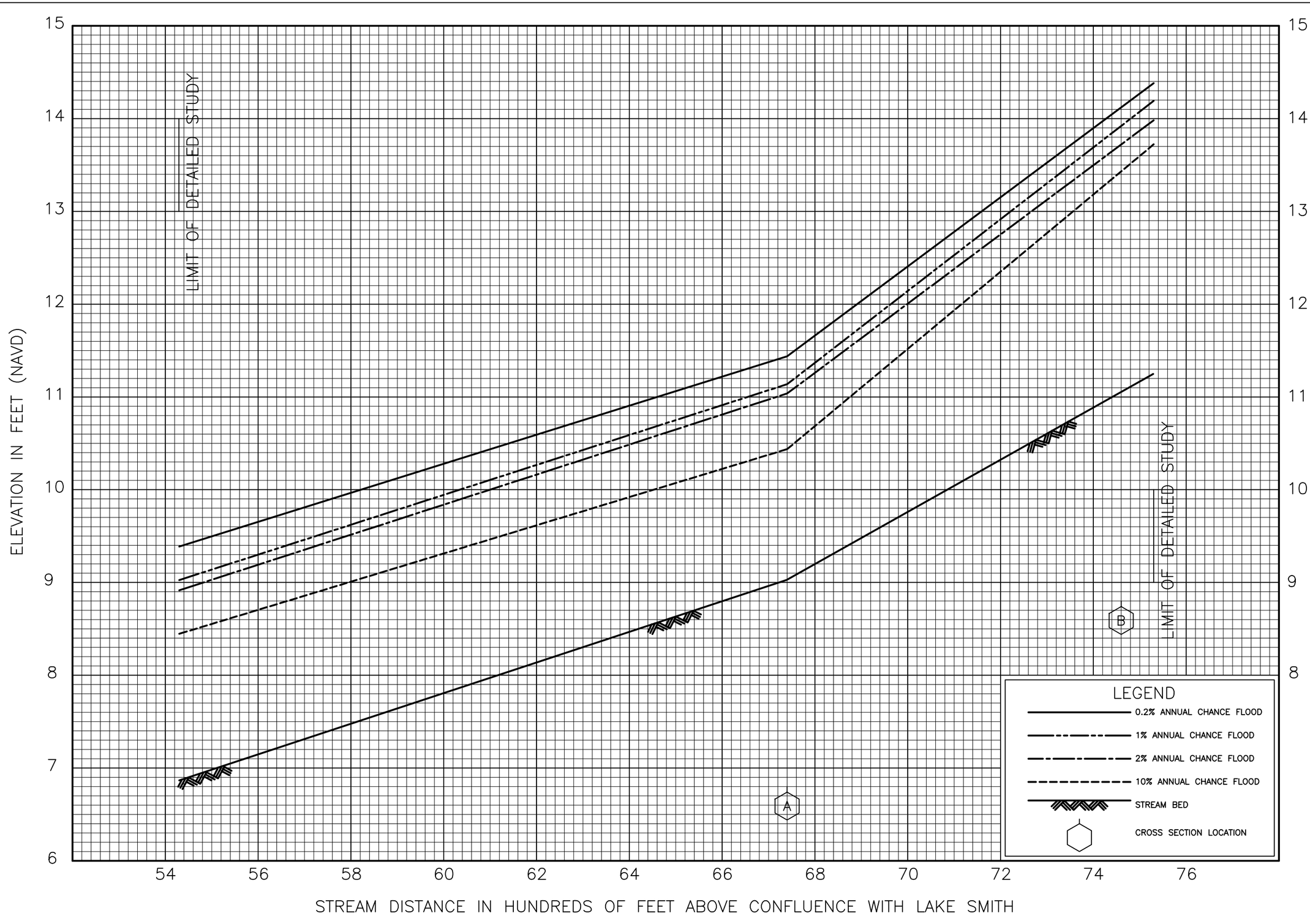
FLOOD PROFILES

LAKE PEMBROKE

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

18P

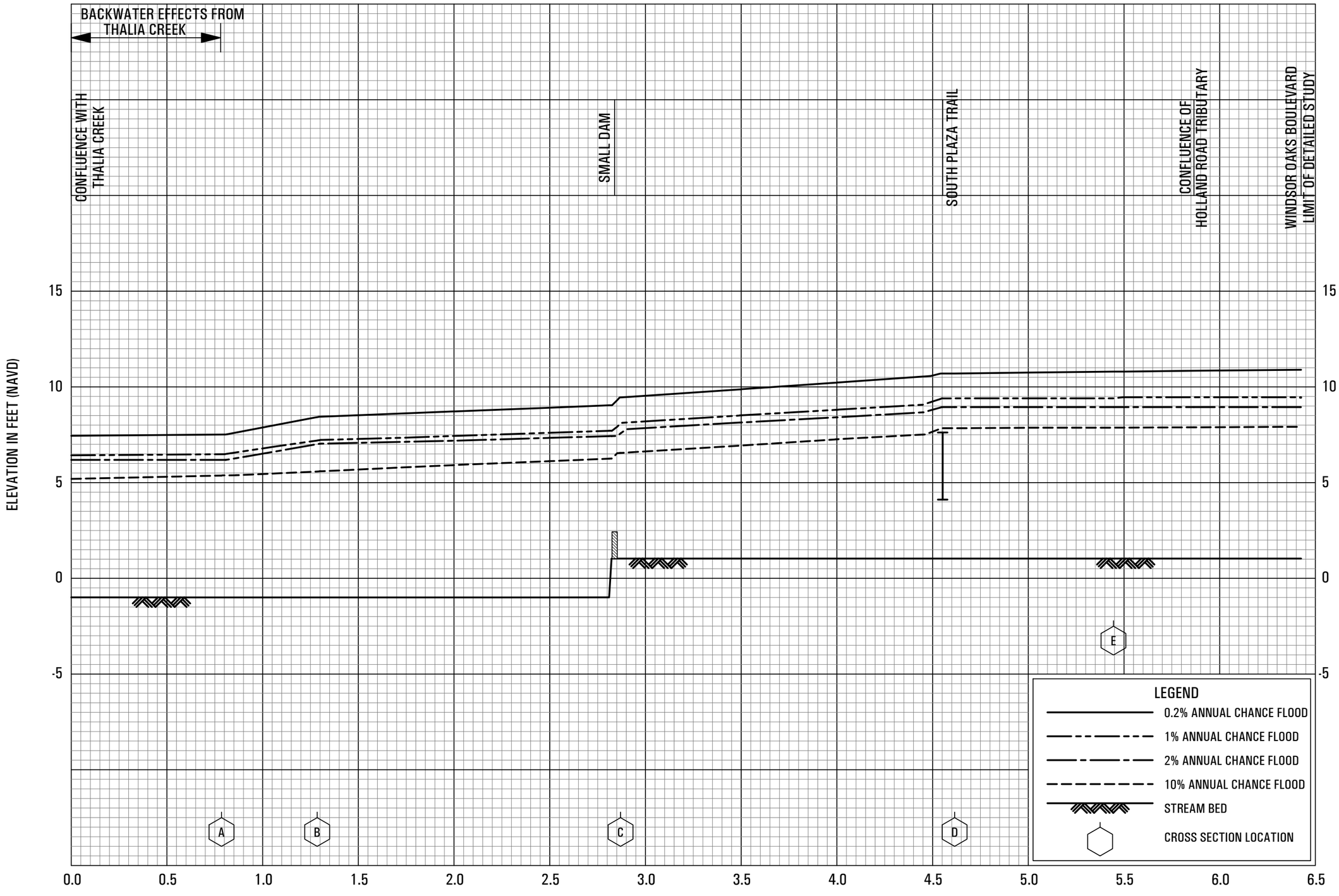


FLOOD PROFILES

LAKE SMITH TRIBUTARY

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH,VA
(INDEPENDENT CITY)



FLOOD PROFILES

LEFT BANK TRIBUTARY THALIA CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA

(INDEPENDENT CITY)

BACKWATER EFFECTS FROM BROAD BAY

CONFLUENCE WITH BROAD BAY

MILL DAM ROAD

ELEVATION IN FEET (NAVD)

25
20
15
10
5
0
−5
−10
−15

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

STREAM DISTANCE IN THOUSANDS OF FEET ABOVE CONFLUENCE WITH BROAD BAY

A

B

LEGEND

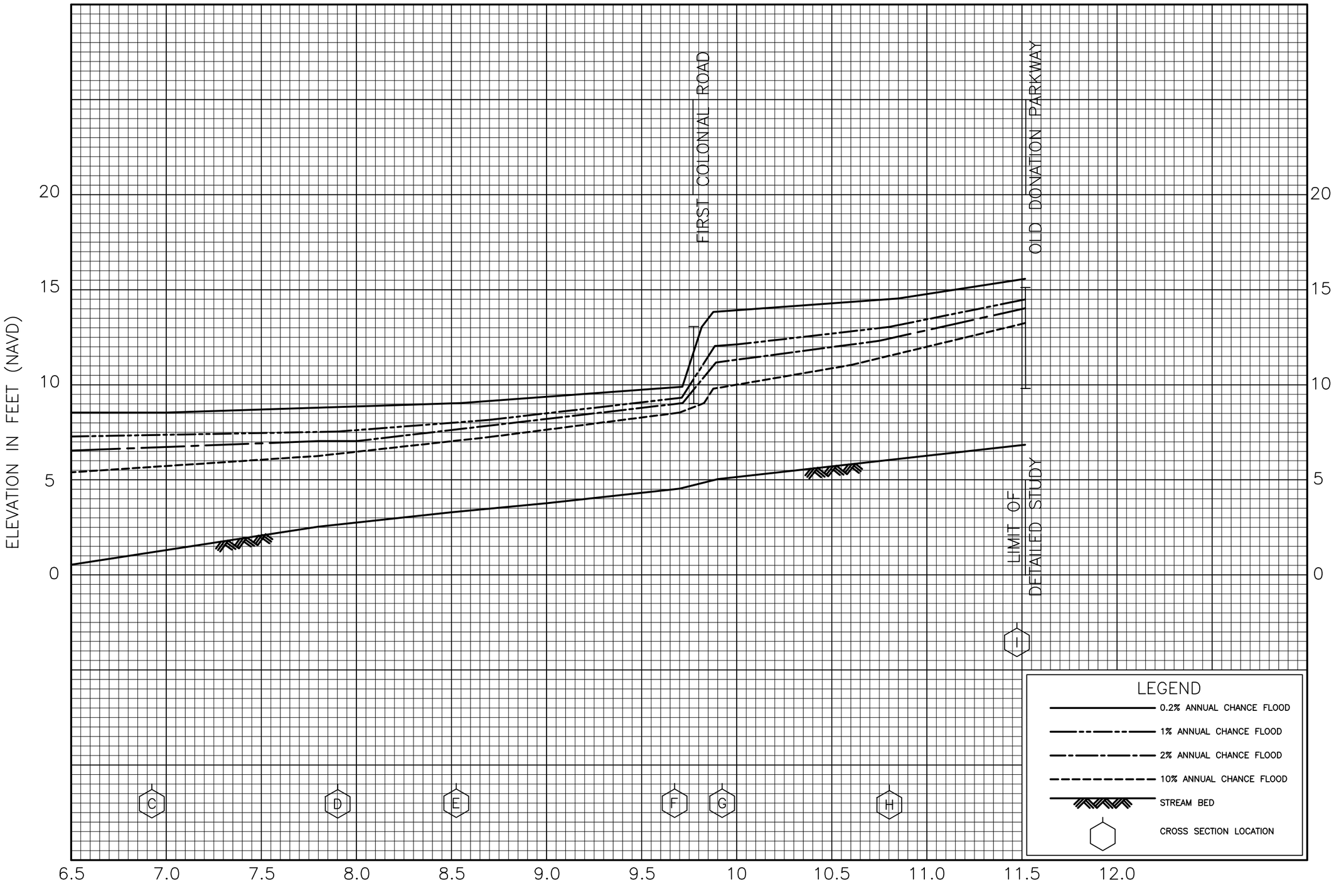
- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

FLOOD PROFILES

MILL DAM CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

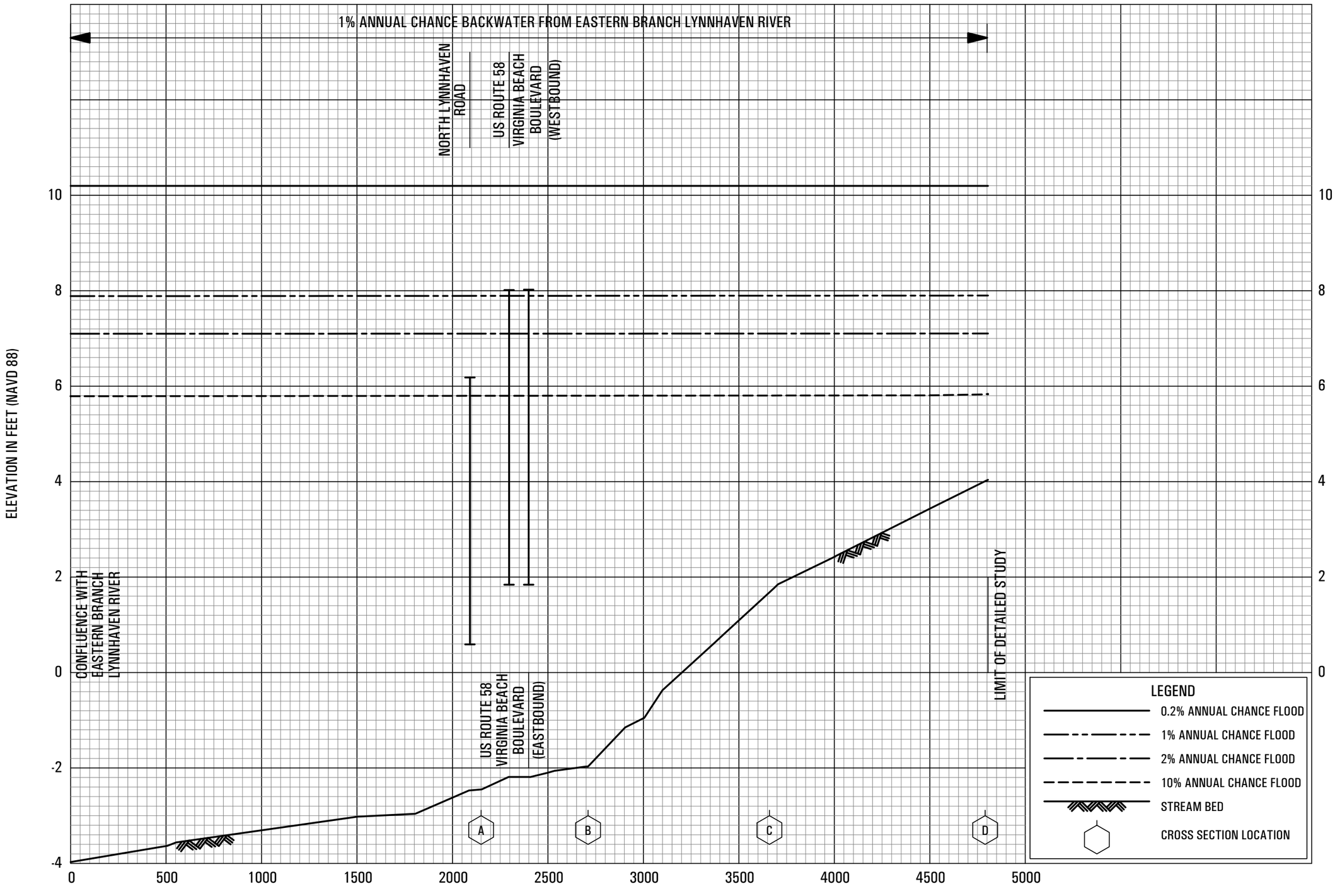


FLOOD PROFILES

MILL DAM CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)



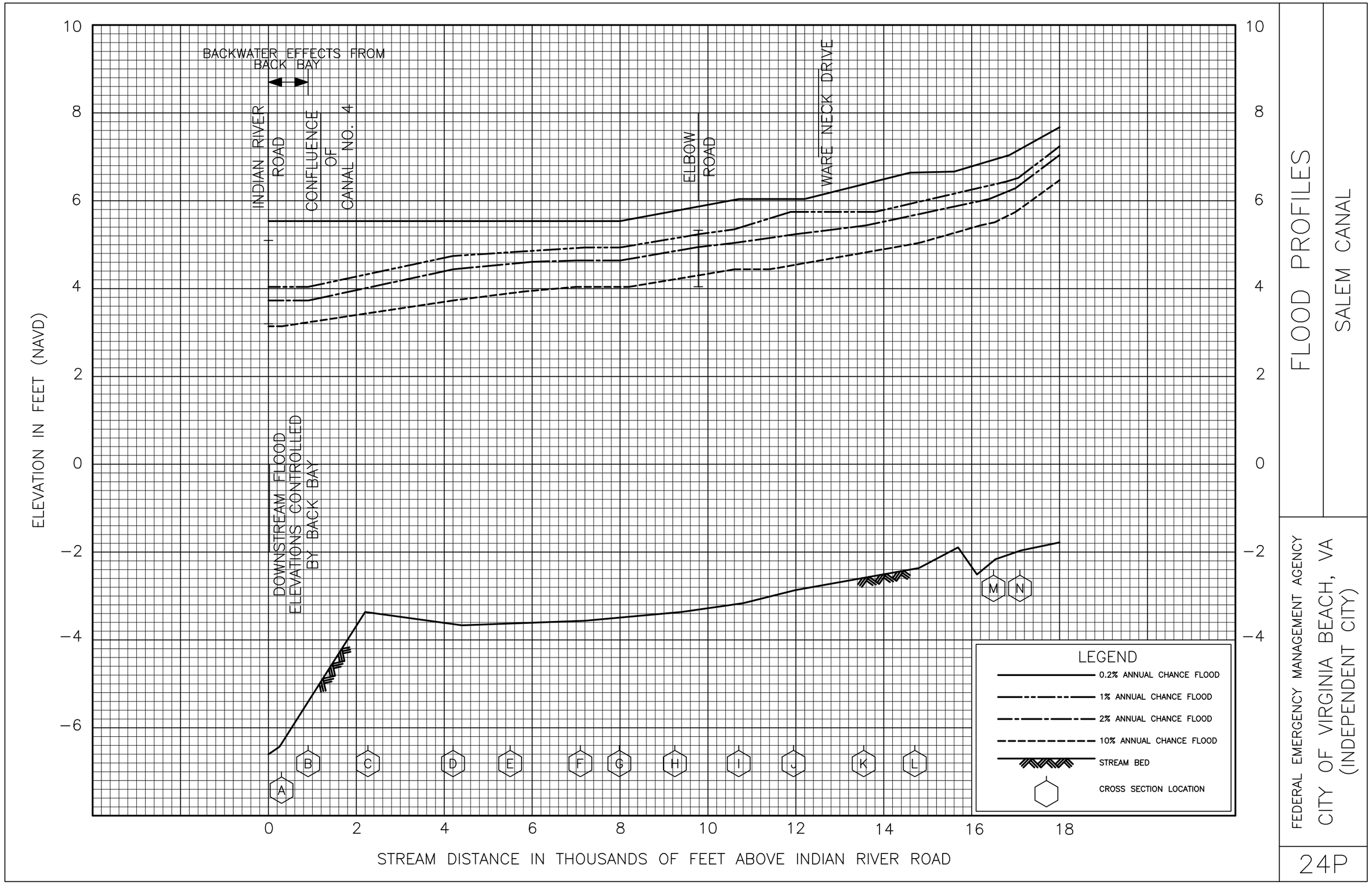
FLOOD PROFILES

PINE TREE BRANCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA

(INDEPENDENT CITY)

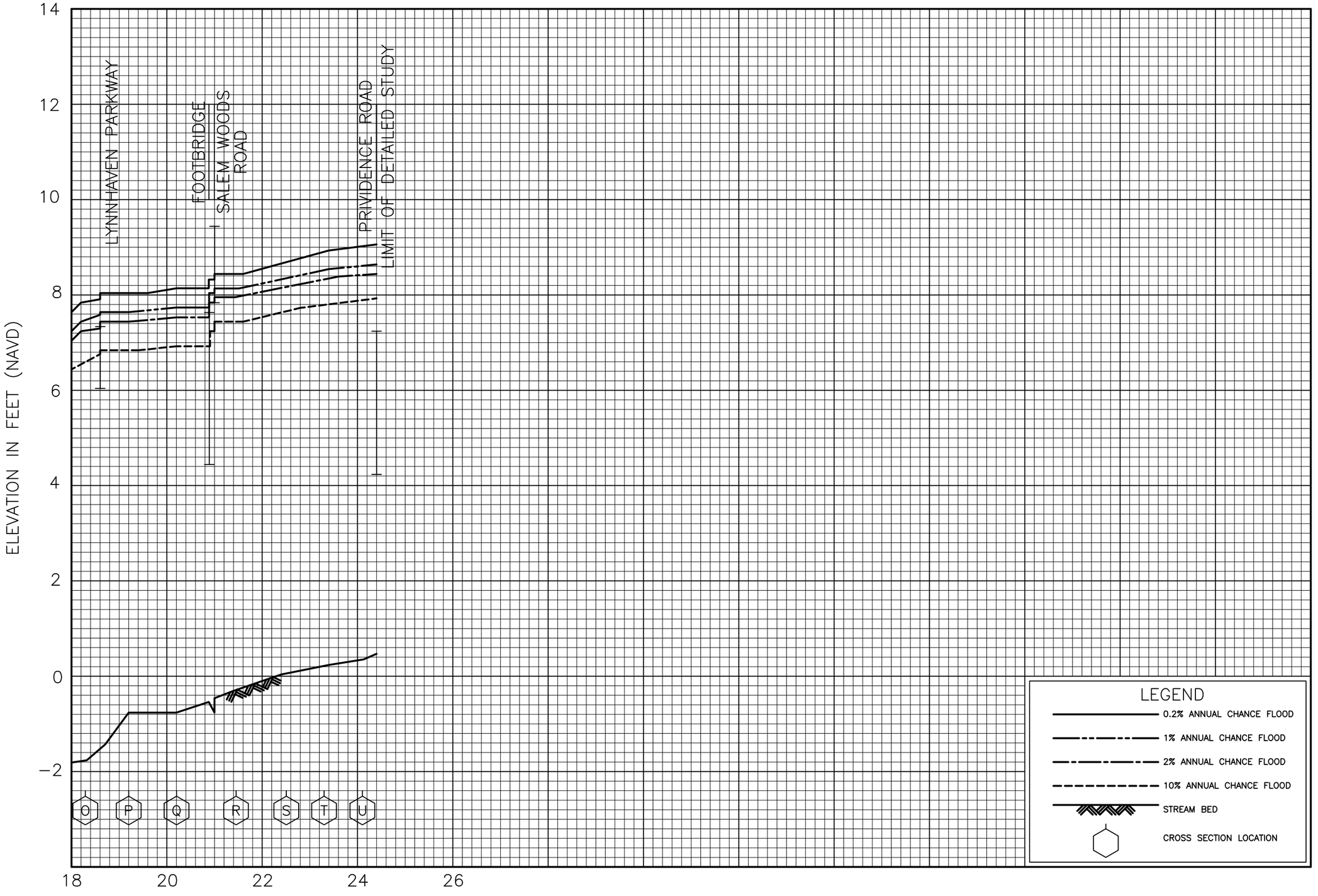


FLOOD PROFILES

SALEM CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

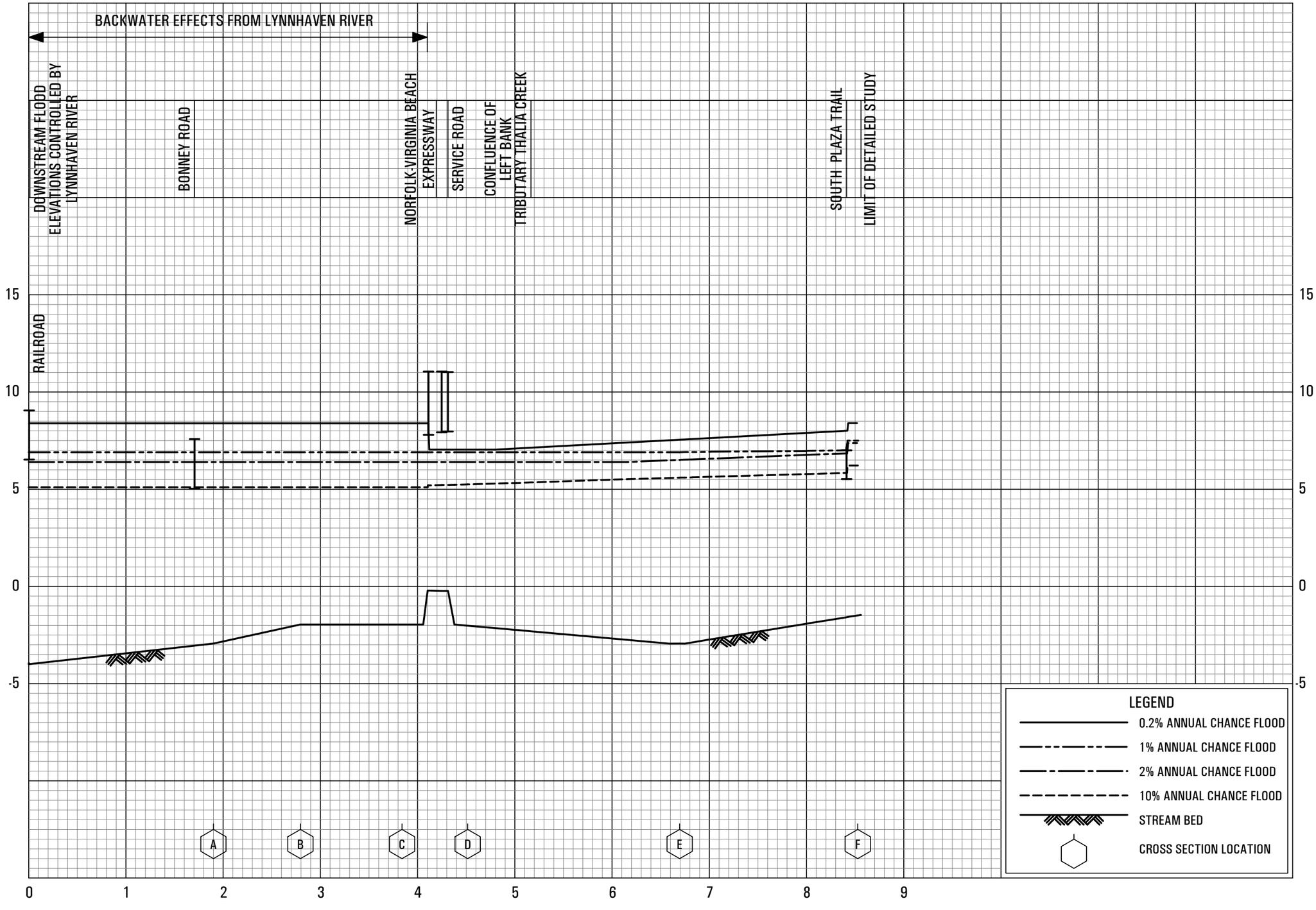


FLOOD PROFILES

SALEM CANAL

FEDERAL EMERGENCY MANAGEMENT AGENCY
CITY OF VIRGINIA BEACH, VA
(INDEPENDENT CITY)

25P



FLOOD PROFILES

THALIA CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF VIRGINIA BEACH, VA

(INDEPENDENT CITY)